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PRINCETON
UNIVERSITY
PRESS

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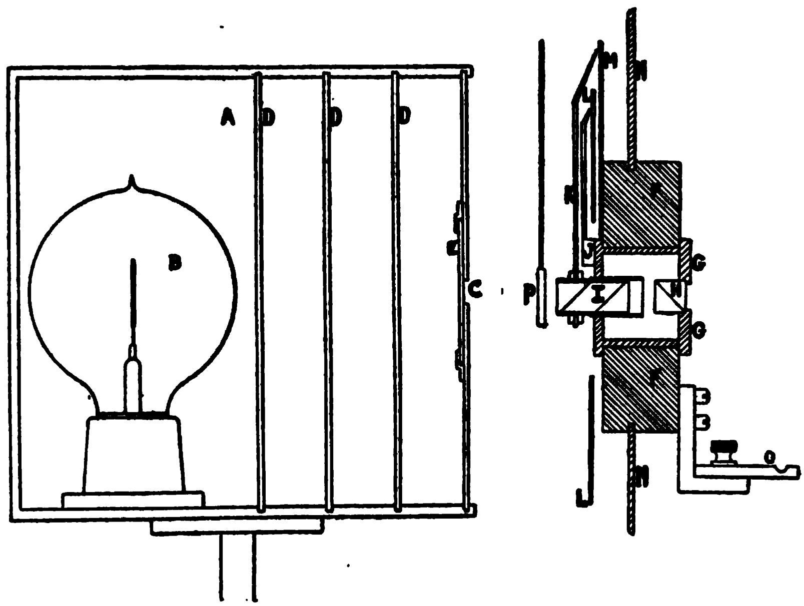
PROBLEM

The problem under investigation was suggested by certain phenomena which have from time to time appeared in astronomical observations. The phenomena in question are briefly as follows. In making judgments on the relative luminosity of twin stars it has frequently been reported that two stars which, seen in the horizontal plane, were estimated to be of equal luminosity were, when viewed in a vertical arrangement, judged to be unequal in luminosity and, in the majority of cases, this inequality favored the lower star. This apparent inequality of the two stars in the vertical arrangement is sometimes as great as two or three magnitudes. The occurrence of these apparently contradictory estimates of two stars, dependent on their relative positions, has been reported by numerous observers. It was brought directly to the notice of Professor Angell by Professor Barnard of the Yerkes Observatory at Lake Geneva. One element which made the phenomena of immediate interest psychologically was the fact that these contradictory judgments do not appear merely as characteristics of the less trained observers, which disappear in continued experience and the gaining of increased facility in this type of observation. On the contrary, they have been reported as a rather persistent factor in the judgments of the most highly trained and accurate observers. This would seem to point to some physiological or psychological basis for the persistent error noted and the problem undertaken in these experiments was to find if any such explanation could be discovered for the observed facts. With this in view, several forms of apparatus were built, the object of which was to expose to the subject two lights, in appearance not too unlike the stars in question, which could be altered in both relative and absolute size and intensity and which could be revolved in a plane at right angles to the subject's line of vision. This permitted of two vertical, two horizontal and an indefinite number of oblique positions in which the two object lights might be shown. The factor of relative size was in-

troduced not because it entered noticeably in the star phenomena but simply because, through the evident close connection of the two facts, the size relations might throw some light on the brightness phenomena under investigation.

FIGURE 1

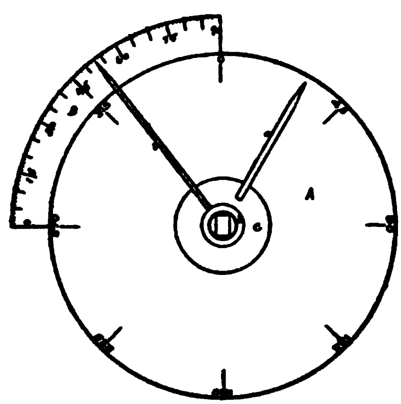


FIRST APPARATUS

A—Light box
B—Lamp
C—Light aperture
DDD—Ground glass diffusion screens
E—Colored gelatine
F—Wooden beam anchored to side walls and floor
G—Eye-piece
H—Double-image prism revolving with eye-piece
I—Nichol prism mounted in separate tube and revolving independently of eye-piece
J—Indicator showing position of eye-piece
K—Indicator showing position of Nichol prism
L—Stationary scale (360°) for indicator J
M—Scale (90°), attached to eye-piece, for indicator K
N—Screen reaching from floor to ceiling
O—Adjustable mouth-piece
P—Small shutter for cutting off light from eye-piece

A possible solution of the problem was looked for along two lines chiefly. First, along the line of a possible difference in sensitivity of the upper and lower halves of the retina, due to the normal difference in the stimulation to which these portions are subjected in ordinary experience. Secondly, an investigation as to whether or not these brightness phenomena could be brought into any sort of relation with the familiar horizontal-vertical illusions of size, such as the horizontal-vertical line illusions, and more particularly, illusions of the "figure 8—letter S" type. A further explanation was also sought in the characteristics of foveal, as contrasted with indirect, vision. It is known that the phenomena in question, under the conditions of astronomical observation, are predominantly, if not exclusively, concerned with the fovea. It was also considered germane to the problem to determine the effect of practice in making this type of judgment, on the appearance of the phenomena in question.

FIGURE 2



First Apparatus

A—Stationary scale (360°) showing the relative positions of the two lights seen by the subject

a—Indicator, attached to eye-piece, moving over scale A

B—90° scale attached to eye-piece and moving with this, showing position of the Nichol prism relative to the double-image prism mounted in the eye-piece

b—Indicator, attached to the tube containing the Nichol prism, moving over scale B

C—Eye-piece

D—Tube containing Nichol prism

FIRST FORM OF APPARATUS

Description

In the first apparatus employed the objective source of light was single. It consisted of a metal box, painted dead black inside and placed on a standard so as to bring its center on a level with the eye of the observer. In this box was mounted a 50-candlepower incandescent light of the type known as "stereopticon," in which the filament is coiled in a circular disk, thus offering a uniform luminous surface on two sides. The front of the box, which slid in metal grooves, had a circular opening cut in its center. By means of other similar fronts, with different sized openings, the size of the object light could be varied. The filament of the lamp was centered with this opening, with one of the circular surfaces at right angles to the line from the subject's eye to the center of the box. Several ground glass slides were placed in grooves at half-inch intervals behind and parallel with the front of the box, between the opening and the lamp. By varying the number of these diffusing screens the intensity of the light was controllable. Additional grooves were provided for colored gelatine screens. Twenty feet in front of the light box was placed the subject's chair, the height of which could be so altered as to put the eye of the subject, seated comfortably, on a level with the light. In front of the subject's head and supported by mental clamps, was a rotating eye-piece in which was mounted a double-image prism of Iceland spar, 1½ inches in diameter. By means of this the single objective light was shown to the subject as two. By revolving the eyepiece the relative positions of the two lights seen by the subject was correspondingly altered, admitting of vertical, horizontal and oblique arrangements. In a metal tube, set into the front of the eyepiece and concentric with the latter, a Nichol prism was mounted. By rotating this Nichol prism through 90 degrees the

relative intensity of the two rays produced by the double-image prism could be continuously altered, from the condition in which one light was entirely cut off and the other appeared at full intensity (minus the slight absorption of the Nichol prism), through the condition in which the two lights appeared objectively equal, to the condition in which the light which was previously cut off appeared at full intensity and the other was entirely cut off.

Separate indicators were attached to the eyepiece and to the tube containing the Nichol prism. The one attached to the eyepiece moved over a stationary, circular scale marked in 10° divisions. The indicator for the revolving tube containing the Nichol prism was furnished with a quadrant scale marked in divisions of 6 minutes each. This quadrant scale was attached to the eyepiece and moved whenever the latter was rotated. It thus retained the same position relative to the two object lights (the two pencils of light coming to the subject's eye from the double-image prism), in whatever position these lights were shown to the subject. From the first scale the relative positions of the two lights was known: from the second, their relative intensity could be computed. Thus, in the 0° position of the eye-piece the lights were horizontal. If the indicator attached to the Nichol prism were then placed at 45°, the two lights were of equal intensity. At 0° of the Nichol prism the right hand light had disappeared entirely and at 90° the left hand light. Movements of the Nichol prism of less than a degree in either direction from the 45° position produced very slight inequalities of the two lights.

The subject's head was placed in a rigid support anchored to the floor. Attached to this by adjustable clamps was an exchangeable mouthpiece, made from wax impressions, into which the subject's teeth were set. A padded clamp came up snugly under the chin. Even slight movements of the head were thus practically avoided. As the apparent distance between the images was a function of the distance from the objective light to the eyepiece, this admitted of alteration within certain limits. A

near position of the light was easily obtained in which the edges of the two lights overlapped. Increase in this apparent separation of the lights was, of course, not at all proportionate to an increase in the distance of the object light from the eye-piece. Beyond 20 feet a relatively large increase in the latter dimension produced scarcely noticeable alteration in the former. It was, therefore, impossible to produce an apparent separation of the lights comparable in extent with that used in the second type of apparatus. They were never judged to be more than 6 - 8 cm. apart. It was impossible to alter the relative size of the lights, except in so far as an apparent alteration took place indirectly, as a result of the changes in intensity. The subject's view of the light, otherwise than through the eye-piece, was shut off by a large screen, reaching from floor to ceiling, which fitted closely around the eye-piece and its support. The light could be shut off from the eye-piece by a shutter in front of the tube. The tube and eyepiece were rotated by means of pulleys, operated from in front of the screen where, also, the indicators and scales appeared and could be read by the operator by the use of a small spot light.

Procedure

With this form of apparatus the general procedure was as follows. The chair, mouth-piece and head-rest were adjusted for the particular subject in question so that, while comfortably seated and without unnecessary strain, the eye to be used was 1 cm. directly behind the eye-piece and the teeth fitted firmly into the mouth-piece. The room, located in the basement of the laboratory, approximated the darkness of an ordinary photographic dark room. The subject was then given 5 minutes to adapt. No effort was made to secure total dark adaptation as the conditions of astronomical observation, in which the phenomena under examination appear, do not involve such complete adaptation. After 5 minutes the subject placed his head in the rest, set his teeth in the mouth-piece and the padded clamp was pushed snugly up under the chin, but without causing discomfort

or strain. The shutter was dropped in front of the revolving tube and the object light switched on.

After the eyepiece and Nichol prism had been set in the desired position, the "ready" signal was given, the shutter raised and the lights appeared simultaneously. There was never any report given that one edge of the lights appeared before the other or that the subject was conscious of the direction in which the shutter moved. They were "not there"—then "there." As soon as the subject's judgment had been given the shutter was dropped and the eye-piece and Nichol prism set for a new position. This was done in front of the screen so that the subject never knew what relation the new position bore to the previous one. Half-minute intervals were given between the judgments in a series of 12, and 3-minute intervals between series. Three such series were given at each sitting, which lasted, therefore, approximately 45 minutes. In a preliminary set of experiments, carried out to determine the point, this rate of exposure was not found to produce fatigue. The chin-rest was dropped and the subject took his head from the head-rest during the 3-minute intervals between series. The right eye was used for the main series of tests but a control series, consisting of about one-third the number of judgments that formed the main series, was taken with the left eye. The order of exposures, both as to the successive positions shown and the relative luminosity of the lights, was regular but was varied in each successive series. All the judgements with this apparatus were, of course, made with direct vision, *i.e.* the images of both lights were always foveal.

Instructions to the Subject

The subject was told that he would see two lights of a certain color but no indication was given him of the position in which they would appear nor of their apparent distance apart. He was asked to make judgments on, (1) the relative luminosity and, (2) the relative size of the two lights shown and, as far as possible, to make these judgments independently of each other, though the judgments might be reported to the operator at one time. He was asked to report the two judgments in the order

in which they were made but no instruction was given as to which should be made first. As far as possible he was to abstract from the relative saturation of the two lights, when such differences appeared, and to make his judgment solely on their relative luminosity. Differences in irradiation were to be neglected in making judgments on luminosity but, where such differences seemed to effect the decision, they were to be reported. He was told that the lights shown him might, in any case, be either equal or unequal and that the inequality, when present, might favor either of the two lights. He was asked to look from one light to the other and give his judgment on size or luminosity or both as soon as he felt any certainty as to equality or inequality. He was requested *not* to attempt to make the lights look either equal or unequal, but in cases in which his judgment changed at any time before the shutter fell he was to report the nature of the change.

In the first part of the work with this apparatus the subjects were all unaware that the objective source of light was single. During the experiments one of them accidentally learned this fact and all were then told. A considerable number of exposures was given, however, in which the Nichol prism was set several degrees away from 45 and the lights which they saw were, beyond possibility of doubt, unequal in luminosity. In these cases the disparity in luminosity of the two lights always carried with it a judgment of inequality in size so that all of the subjects were convinced of the possibility, in spite of the unitary light source, of two lights being shown them that were unequal in both size and brightness.

The subject was asked to report in his introspection any isolated or recurrent characteristic of his process which came to notice; any cases of association, peculiarities of physical or mental condition, appearance of fatigue, noticeable after-images, etc.

Subjects

The subjects in the experiments with the first apparatus were Dr. M. R. Fernald, Dr. E. M. Chamberlain, Dr. C. J. Weiden-

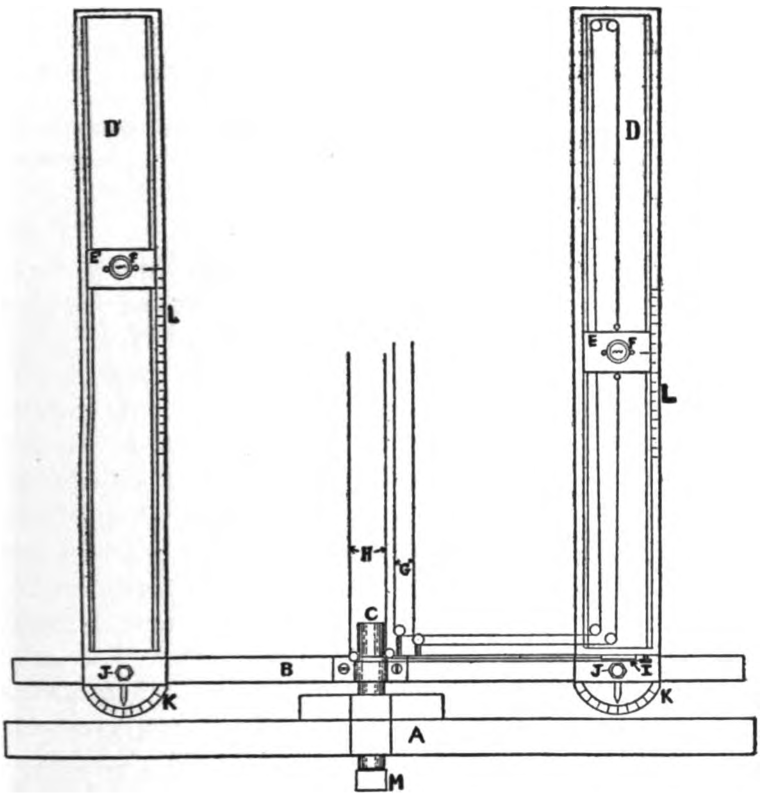
sall and Dr. M. H. S. Hayes, all graduate women students in the Psychological Laboratory of the University of Chicago. A series of results was taken with the writer as subject but these were, of course, not comparable with the other series. These were made in order to more adequately interpret the introspections of the different subjects. All of the subjects had served in laboratory experiments and were competent observers and introspectors. All were normally right-handed. No astigmatism or muscular trouble was reported, and only one subject wore glasses. Subject C was slightly hypermetropic and wore glasses intermittently for reading. No differences in visual acuity of the two eyes was reported by any subject and optical tests on reading with graded types failed to demonstrate any such difference. C's. and W's. judgments were uniformly given with decided promptness and a large amount of subjective certainty. H's. and F's. judgments were given more slowly, more hesitatingly and with less apparent certainty of their correctness. All four subjects occasionally made the remark that the appearance of the lights had changed during the process of judging and it was sometimes reported that this seemed to be the immediate result of involuntary eye movement. No variation in procedure occurred affecting one subject only. The introspective account of all four subjects was relatively full at first. In the later series a large part of the introspective reports was made up of repetitions or slight variations from the earlier accounts. F. asked for more specific instructions on the relation of saturation to the judgments on relative luminosity and these same instructions were then given to the three other subjects. The remark was frequently made by all of the subjects that in many cases the judgment of preference for one light was little more than a vague suggestion of greater intensity or size and no certainty was felt as to its objective validity. Three of the subjects remarked on the coincidence that the judgments of greater size and luminosity, where both appeared, generally went together and the larger was rarely judged to be the dimmer, or vice versa. None of the subjects realized that only the factor

of intensity in the two lights suffered unequal modification and that, throughout the experiment, they were always equal in size.

Results

The results with the first form of apparatus were wholly negative. The phenomenon failed to appear in any consistent way, not only throughout the results of all four subjects taken together but throughout the results of any one subject. Not only did the phenomenon in question fail to appear with any consistency, but the judgments were equally erratic in their tendency to favor any one light, either in the horizontal, vertical or oblique positions. Lights of relatively distinct inequality were occasionally misjudged, the dimmer being judged the brighter, and the reverse, while pairs of slightly unequal lights were frequently misjudged in this way. The occasional remark of subjects, that the relative intensity of the two lights seemed to change during the process of making a judgment and that this happened with equal frequency in the different positions, was supplemented by the opinion of two subjects that the change occurred as the direct result of slight involuntary eye movements. A series of judgments was therefore made on two of the subjects and on the writer to determine the extent to which the judgments could be altered by voluntary eye movements, the conditions of observation being the same as in the original judgments, *i.e.* mouthpiece, chin-rest, etc. The results did not show the alteration of judgments as the result of voluntary eye movements in as striking a manner as had been expected from the introspective reports of the subjects, and this may in part account for the failure to discover more promptly this radical fault in the technique with the first type of apparatus. This series of experiments did, however, show the modifiability of judgments by eye movements with sufficient clearness wholly to invalidate the results with this type of apparatus. The results of this first set of experiments are, consequently, not given.

FIGURE 3



SECOND APPARATUS

A—Tripod
B—Revolving arm
C—Steel axis on which B revolves
D—Variable light tunnel
D'—Standard light tunnel
E—Variable light-car
E'—Standard light-car
FF—Miniature electric lights
G—Cords, connected with wheel at side of subject's chair, for moving the variable light-car
H—Cords, connected with lever at side of subject's chair, for controlling iris diaphragm on variable light tunnel
I—Iris diaphragm
JJ—Pivots for adjusting angles between light tunnels and revolving arm

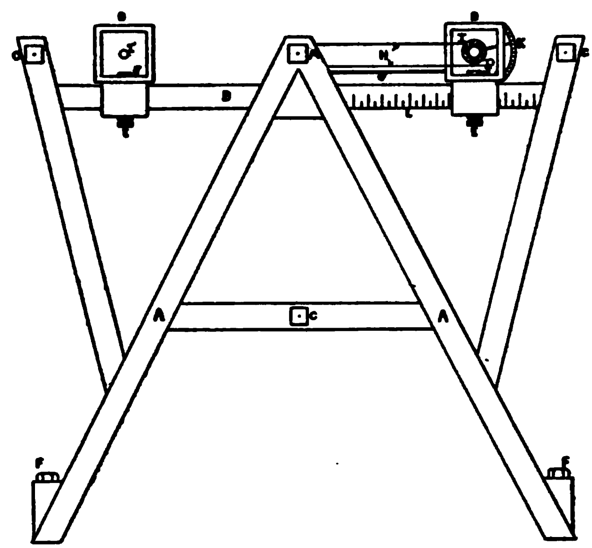
KK—Scales which show the angles formed by the light tunnels and the revolving arm

LL—Mm scales, running the length of the light tunnels, which show the position of the light-cars

M—Light-box with pinhole light, used for central fixation in indirect vision judgments.

The peripheral fixation light boxes (shown in figure 4) are omitted.

FIGURE 4



SECOND APPARATUS

A—Tripod

B—Revolving arm

CCC—Light boxes with pinhole apertures for peripheral fixation. The fourth peripheral light box (not shown) was hung from the ceiling

DD—Light tunnels containing the two movable light cars

EE—Milled screws for securing light tunnels on revolving arm

FF—Bolts securing tripod to cement floor

G—Cords, connecting with wheel at side of subject's chair, for moving the variable light car

H—Cords, connecting with lever at side of subject's chair, for controlling iris diaphragm on variable light tunnel

I—Iris diaphragm

I'—Light aperture of standard light tunnel

JJ—Pivots far adjusting angles between light tunnels and revolving arm

K—Scale for showing size of opening in iris diaphragm

L—Scale, extending the entire length of revolving arm, for setting light tunnels at different distances apart

M—Light-box with pinhole light, used for central fixation in indirect vision judgments

The individual exposure shutters for the two object lights are not shown. The fan-shaped shutters used were attached to the bases of the light tunnels and were connected by belts so that they could be moved simultaneously by the operator.

The third leg of the supporting tripod, which projected forward, is not shown in either of the drawings of this apparatus.

SECOND FORM OF APPARATUS

Description

In this apparatus two objective lights were used which permitted of alteration in relative and absolute size, as well as in relative and absolute intensity. It was also possible to vary the actual distance between the lights from 30 cm. to 1 m. The sources of light were two miniature incandescent lamps of 6 candlepower each, connected in parallel wiring with a set of storage batteries. These lamps were mounted on small cars which moved along tracks 16 cm. wide, running east and west. The front end of each pair of tracks was secured, by means of pivot running through a crosspiece, to a revolving arm 1 m. 30 cm. long. This arm, revolving in a plane the horizontal dimension of which ran north and south, was hung at its center from a metal axis which projected backward from the apex of a tripod. This, in turn, was firmly anchored to the floor. By means of side pieces the two pairs of tracks were inclosed at top, bottom, sides and rear with heavy black cloth forming two light proof tunnels of sufficient height to permit the cars to run freely backward and forward on the tracks. One of these tunnels was closed in front by a black screen which had a round aperture cut in its center. The size of this, the standard light, was changed by substituting other screens with different sized aperatures. Grooves were provided for screens of colored gelatine. The front of the second tunnel was closed in the same manner except that an iris diaphragm was set into the opening in the screen, admitting of a continuous change in the size of the light shown the subject, from 0 to 3 cm. This diaphragm was controlled by a lever at the side of the subject's chair. This was connected with the diaphragm by means of cords running over pulleys and so arranged that neither change in the separation nor in the position of the lights altered the control. A scale at the front of the tracks registered in degrees

the amount of movement of the diaphragm and could be read by the operator.

The lamp-car of the "Standard Light" could be fixed at any position from 25 to 120 cm. back of the opening in the screen. The car in the other tunnel was moved back and forward through the same range by means of two cords running over pulleys, which passed out the front of the tunnel, thence to the axis of the revolving arm, to the rear wall of the room, to the ceiling and, finally, to a wheel clamped at the side of the subject's chair. By rotating this wheel the subject was able to run the car forward or backward until a position was reached where he judged this light to be equal in intensity to the standard light. In the following descriptions this light, the luminosity and size of which could be controlled from the subject's chair, will be referred to as the Variable Light or the Variable Car in contradistinction to the Standard Light or Car which was set in a fixed position by the operator before each judgment or series of judgments. The positions of the two cars were read from millimeter scales running the length of the two pairs of tracks.

The distance between the two lights was altered by moving the pairs of tracks in or out on the revolving arm, where a scale gave their position. For each position the rear ends of the tracks were swung outwards from the main axis far enough to make the long axis of each tunnel coincide with the continuation of a line from the subject's eye-piece to the center of the opening in the front of each tunnel. The amount of this angular displacement for each separation of the lights was indicated by a quadrant scale placed under the front of the tracks, centered around the pivot by which the tracks were attached to the revolving arm. The cars thus moved backward and forward along the direct line of sight of the subject. By swinging the revolving arm the standard light could be placed directly above or below the other, to right or left of it in the horizontal position, or in any one of the oblique positions. The tracks were made rigid at the rear by wire guys to the ceiling and walls. These had to be shifted at each partial revolution of the arm and tracks.

Owing to the complexity of the connection of the light car with the wheel on the subject's chair, a second form of control was later substituted. The wheel was connected by a cord with an indicator running along a scale on the wall, of the same length as the tracks themselves. The operator then moved the car by a short cord in accordance with the wishes of the subject as indicated on the wall scale. The diaphragm was moved in accordance with a similar indicator connected with the lever at the side of the subject's chair and running on a second wall scale.

The arrangement of the subject's chair was much the same as in the first apparatus, except that the mouthpiece was not used as in the previous case and a stationary eye-piece without prism replaced the revolving prism eye-piece of the earlier form. On the front end of the main axis (of the revolving arm) and on a line connecting the two object lights a miniature incandescent lamp was mounted. A small light-tight box was fixed over this, having a pinhole opening in the center of its front side. Ground glass screens provided for controlling the intensity. This pinhole light served as a central fixation point for judgments in indirect vision. Similar fixation points were placed 50 cm. directly above and below the central fixation point and to right and left in a horizontal line. Individual shutters were placed in front of the two object lights and connected in such a way that they could be raised at the same moment by the movement of a single lever, thus simultaneously exposing the two object lights. A large screen midway between the subject's chair and the revolving light apparatus cut off objects outside the circle in which the lights revolved and a shutter in front of the eye-piece was dropped between judgments. The connections of the two lamps on the light cars were run through rheostats. They could also be placed, separately and without breaking their connections, in a Max Kohl photometer which was supplied with a standard lamp connected with separate storage battery. The photometer could also be placed in front of the apparatus and the relative intensity of the two lights at the openings thus measured. The intensity of the standard light, placed at the

60 cm. division in the light tunnel, was 2 candlepower, as measured by the photometer. This apparatus, by permitting variations in the relative size and a much greater separation of the two lights, overcame the two chief difficulties of the first apparatus. It was, however, impossible to bring the lights closer together than 30 cm.

Procedure

First Set of Experiments

In the first set of experiments with this apparatus the procedure, as far as it concerned the subject, was much the same as with the first apparatus. The head-rest was adjusted so as to bring the subject's eye directly opposite the eye-piece. Five minutes were given for adaptation, the shutter was dropped, the lamps on the two light-cars switched on, the "ready" signal given, the shutter in front of the subject's eye-piece raised, the judgment on luminosity and size reported, and the shutter dropped again. The lights shown in this set of experiments were objectively equal in both luminosity and size. The object of these experiments was, then, to determine whether the lights would be persistently overestimated in one or more of the four positions (upper, lower, right or left).

The time between judgments was necessarily longer than with the first apparatus owing to the greater time required in setting the light-cars, adjusting the iris diaphragm and swinging the tracks to a new position. The time averaged 2 minutes. It was impossible to make this time absolutely uniform as the rotating mechanism did not work with uniform smoothness and any particular shift might take a longer or shorter time than the preceding one. This was not thought to interfere with the validity of the results as the time was always sufficiently large to prevent fatigue and total dark adaptation was never sought. The subject removed his head from the rest between judgments and resumed the position again at the ready signal. The rest fitted snugly and the possible change of position was very slight. Considering the length of time taken between judgments and

the consequent duration of a series it was felt that absolute fixity of position was impossible without a mouth-piece (if, indeed, it could be obtained even in that way). The necessary strain and discomfort incident to a long series with the mouth-piece was felt to more than offset the disadvantage of such slight shifts in position as were possible with the method used. In order to ascertain the effect of a slight shift in the position of the subject's eye a series of results was taken in half of which the eye-piece and head-rest were moved 2 cm. to the left of the original position, in the other half they were moved the same distance to the right. This alteration of position was many times that which was possible for the subject's head while in the head-rest. The results showed absolutely no corresponding effect, either in general type or mean variation. The sittings lasted about 50 minutes and 16 exposures were made. The order of positions of the lights was, as with the first apparatus, regular but was changed in each successive series.

Instructions to Subject

These were practically identical with those given in the experiments with the first apparatus. The subjects were told what to look for and how to make their judgments, but no indication was given of the nature of the problem or the actual character of the lights in any case. Introspection on the process of judging was asked for; also on any isolated or persistent phenomena directly or indirectly connected with the judging process.

Second Set of Experiments

In this series the subject, instead of simply making a judgment of equality or inequality between two lights which remained constant and objectively equal during the process, altered, by means of the wheel and lever at the side of his chair, the size or intensity of one light until he judged it to be equal to the other in that respect. The procedure was as follows. After the subject had adapted for 5 minutes and the shutter had been dropped, the standard light-car was fixed at a medium position

on the mm. scale running the length of the track and one of the fixed aperture slides, containing an opening midway in diameter between the extreme limits of the iris diaphragm, was placed in the groove at the front of this track. The other light-car was placed at the front of its track, making the light of maximum brightness, and the iris diaphragm was opened to its widest extent. When the lights were exposed, in the regular way, the subject first moved the wheel until the luminosity of the brighter light was reduced to equality (in his estimation) with that of the standard light. The lever was then lowered until the size of this light was likewise reduced to equality with that of the standard light. If, as generally happened, this change in size affected the, previously determined, apparent equality in luminosity, this latter was further altered until a new position was reached which satisfied the subject in regard both to luminosity and size. This sometimes required several alternate manipulations of the wheel and lever. These successive alterations were, however, permitted only in case the additional variation was in the same direction as the first and principal one. If, on the contrary, after the alteration in size the subject felt that the previous change in luminosity had been too great and that his light was now the dimmer, he was not allowed to bring it back again to what he considered a position of equality. In this case the entire judgment on size and luminosity was begun again. When a position of both light-car and diaphragm had been reached which satisfied the subject, the shutter was dropped, any introspection was given, and the operator read from the two scales the position of the variable light-car and the size of the opening in the iris diaphragm which had been judged by the subject to make that light equal to the standard in luminosity and size. The light-car was then moved to the extreme rear of the track and the iris diaphragm reduced to its smallest opening. The subject's procedure in this case was identical with that in the preceding judgment, except that the wheel and lever were moved in the opposite direction and the size and luminosity of the variable light were, consequently, increased to apparent equal-

ity with the standard light instead of being decreased, as in the previous case. After one judgment made by increasing and one by decreasing the size and luminosity of the variable light, the revolving arm and tracks were swung to a new position and two similar judgments made in the new position.

The averages between the positions accepted as equality, on the one hand by reducing and on the other by increasing the variable light, were accepted as the actual judgments of equality. The difference between the actual position of the standard light and aperture and the average of all the positions judged equal in reducing the luminosity and size of the variable light gave the average error for that type of judgment and in the same manner for the judgments formed by increasing the size and luminosity. The average difference between the averages of these two types of judgments and the actual position and size of the standard light gave the average error for this series. The shutter was dropped as soon as the subject signified that he was satisfied with the size and intensity of the lights. The time allowed between a judgment in which the variable light was decreased and the following judgment in which it was increased was 1 minute. Between two pairs of such judgments the time averaged 2 minutes, as in the first series with this apparatus and, for the same reason as in that case, it was not absolutely uniform. The sittings averaged between 50 minutes and 70 minutes and 12 pairs of lights were exposed. The time for carrying out this form of judgment was necessarily considerably longer than that required for the simple judgment of equality or inequality made in the first set of experiments with this apparatus.

Instructions to Subject

These were necessarily quite different from those given in the earlier series. The subject was told that two lights of a certain color would be shown him. In case they appeared unequal,—and in this series the disparity at the start was so gross that they were never judged to be equal,—the subject was to increase the size and luminosity of the smaller and dimmer (or to de-

crease these factors in the larger and brighter light) until he was satisfied of their equality in both respects. It was thus necessary to indicate which was the standard light. In the trial cases, in which this information was not given, the subject not infrequently tried to reduce the brightness of the standard light instead of increasing the other and when he became aware of his error was forced to alter his mental attitude to an extent that often affected his judgment when finally formed. This appeared both in the general type and mean variation of the results and in the introspective account of the subject. He was allowed to decide for himself the best way of making the adjustments—whether, for instance, relatively short, quick movements of the light and diaphragm or a steady, uniform increase or decrease produced the better effects. He was warned that, if he carried the adjustment of the changing light or diaphragm too far in any case, he would not be allowed to drop back again to a satisfactory position but would have to start again from the beginning. The instructions as to irradiation, saturation, etc. were the same as in the previous cases. Also the request was made for reports on any related phenomena, peculiarities or incidental variations in the process, or in his own feeling about the process or result.

A modification in the procedure with this apparatus occurred when the wall indicator was substituted for direct control of the moving light-car by the subject. (See description of apparatus, page 16.) This modification affected the operator only, however, and left the subject's method of making judgments the same as before. Most of the subjects were unaware that any change had been made during the entire series of experiments with this form of apparatus. The one who did find it out did so by accident and not as a result of any difference which occurred in his own procedure. The operator now moved the light-car by means of a short cord running through the tunnel, and the diapraghm by means of a lever extending below the tracks. The light-car was moved so as to correspond, in its position on the mm. scale, which ran lengthwise of the tracks

and in rate of movement, with the position and rate of movement of the indicator on the wall scale as this was moved by the subject. The same was true of the movement of the iris diaphragm, as indicated by the circular scale which showed the size of the iris diaphragm.

Third Set of Experiments

In this set the procedure, as far as concerned the subject directly, was the same as in the first set with this apparatus. The subject made judgments of equality and inequality on two lights, vertically and horizontally placed, which remained constant during the judgment. Unlike the judgments of the first set, however, these were made on lights which were objectively unequal in either size or luminosity. The object was to determine exactly the range of positions of the variable light-car and iris diaphragm inside which this light was preponderantly judged as equal to the standard light, the latter remaining fixed in size and intensity. Also to determine whether this range was greater in the horizontal than in the vertical positions of the lights. Two positions were first determined for the variable light-car, in the first of which this light was always judged brighter, in the second always dimmer than the standard light. Similar limits were established for the iris diapraghm. The variable light-car was placed, in an irregular series, at each mm. division inside this range and compared with the standard light, the size remaining constant during this series and equal to that of the standard light opening. The iris diaphragm was then, in a similar series, placed at each quarter mm. division inside limits (determined as in the previous comparison of luminosities) and compared with the standard light, the brightness remaining constant and equal to the standard light. This was carried out in all four positions of the lights. The detailed procedure in this set was practically identical with that in the first series with this apparatus.

Fourth Set of Experiments

In this series the procedure was identical with that in the second set with this apparatus, after the change from direct control of the car by the subject to control by an indicator, except that the subject's left eye was used instead of the right. No additional instructions were given beyond a request that the subject report any characteristics of the procedure which seemed to be dependent on the change from the right to the left eye.

Fifth Set of Experiments

This consisted of two parts, in both of which the judgments were made in indirect vision. In the first part, the central fixation point, attached to the front of the main axis (see description of apparatus, page 16), midway between the two lights, was used. In the second part the fixation points placed 50 cm. from this axis and on a line at right angles to the revolving arm, were employed. In this second part, one half of the exposures in which the object lights were placed vertically was made with the fixation point at the right; the other half with fixation at the left. In the horizontal exposures, one half had the fixation point above and the other half below. The procedure in both of these series was practically the same. After adaptation the shutter was dropped in front of the subject's eyepiece. The two object lights and one of the fixation lights were switched on and the two shutters in front of the object lights were set. The shutter in front of the subject's eyepiece was then raised and the subject fixated the small fixation light. The ready signal was given and the shutters in front of the object lights released exposing the two lights simultaneously. The subject gave his judgment on size and brightness and the eyepiece shutter was dropped. The lights were swung to a new position and the process repeated. The interval between exposures was the same as in the first set with this apparatus, as the setting of the shutters in front of the lights did not occupy more than three or four seconds.

Instructions to Subjects

The subject was told to fixate the small pinhole light which alone was apparent when the eyepiece shutter was raised and to hold this fixation with as little eye movement as possible during the judgment. In case he felt that his eye had moved an unusual amount he was asked to report that fact. This included any possible case in which his eye had been allowed to wander to one or both of the object lights. He was asked to try and keep, as far as possible, his judgments of size and luminosity separate and not make judgments favoring one light in both attributes because he felt sure that one was brighter or larger. The instructions as to the character of his judgements, *i.e.* the factors of saturation, irradiation, associative phenomena, secondary phenomena, etc., were the same as in the first set with this apparatus. He was also asked to report on any unusual eye strain incident to this use of indirect vision. As this form of judgment was, for most subjects, more fatiguing than were those made with direct vision, an additional interval was allowed after each four exposures. This necessarily cut down the number of exposures possible in a 50 minute sitting.

Sixth Set of Experiments

In the first half of this series the iris diaphragm was set with its diameter equal to the opening of the standard light. The subject then alternately moved the variable light-car back from the position of maximum luminosity to a position in which he judged this light equal to the standard light, and brought it forward from minimum luminosity to equality. The judgments in this half of the series were, thus, made on luminosity alone. In the second half they were, similarly, made on size only, the brightness remaining equal. The procedure was the same as in the second set with this apparatus, except that here only one factor was manipulated and judged at a time.

No additional instructions were given except that the subject was warned of the variation in procedure of this series as com-

pared with the second set with this appartus, in which, also, the judgments had been made by means of the control wheel and lever.

SUBJECTS

With the second form of apparatus the subjects were Dr. M. R. Fernald, Dr. M. H. S. Hayes, Dr. A. H. Sutherland, Dr. H. H. Adams and Dr. H. A. Peterson. All were graduate students in the Psychological Laboratory of the University of Chicago. All had served as subjects in laboratory experiments and were competent observers and introspectors. S. had, some months previously, received an injury to the cornea of the right eye and, on finding that his average error was several times that of any other subject, his results were thrown out and do not appear in the tables. Of the remaining four subjects only one, A, wore glasses. Subject A was astigmatic in both eyes but considerably more so in the left than in the right. He was also somewhat hypermetrophic in the right eye but not in the left. He reported a tendency to fixate distant objects (over 7 ft.) with the right eye and near objects with the left. This astigmatism and hypermetropia were adequately corrected by glasses and no visual difficulty in ordinary work was reported. He did not report the experiments as noticeably fatiguing.

The results of the different subjects cannot be regarded as absolutely comparable as H. and F. had served throughout the previous series while P. and A. were new to the experiment. The radical difference between the first apparatus and the second, from the subject's standpoint as well from that of the operator, tended to minimize the importance of this difference, *i.e.* practice with the first form of apparatus would be of only slight value in making judgments with the second form.

In all of the series with this apparatus, both those in which the subject simply made a judgment on two constant lights and those in which one light was controlled by the wheel and lever mechanism, P.'s judgments were given much more slowly than those of the three other subjects and were given with less ap-

parent certainty. His introspections were, also, less complete than those of F. and H. The judgments of F. and H. were very much as in the series with the first apparatus, except that in the judgments made by controlling one light they were necessarily much slower. In this latter form F.'s judgments were particularly painstaking and consequently slow. The introspection of both F. and H. was full throughout. A.'s judgments were given with considerably greater rapidity than those of the other three subjects, though he did not show any noticeably greater certainty than did the other subjects. His introspective reports were less complete than those of F. and H. The difficulty in being certain that the judgments on intensity were founded solely on differences in luminosity and not, in part, on differences in saturation was reported by all the subjects. P. had decided difficulty with the indirect vision series and felt rather unsatisfied with most of his results. The wheel and lever control offered some difficulty to most of the subjects during the earlier series and, to overcome this, three practice series were made with each subject, the results of which were not used. A. and P. were especially apt, both with the light-car and the iris diaphragm, to run over the point where, in their final judgment, they regarded the lights as equal and were forced to start the judgment again from the beginning. A. was the most suggestible and F. the least. In no case is there any indication that F. ever reacted to the "probability" that one light was larger or brighter. A. undoubtedly did react in this way on some occasions and H. and P. apparently did in a few cases. All of the subjects were carried through a uniform series of equal length and no variations were introduced effecting one subject only. No difference in the acuity or range of vision of the two eyes not corrected by glasses was reported by any of the subjects and there was no case of astigmatism affecting different meridians in the two eyes. As with the first apparatus a series of results was taken with the writer as subject and for the same reason.

Results

The results with this form of apparatus were on the whole negative. Those for the first set of experiments in which the distance between the lights was 1 m. or ½ m., were wholly negative. In the judgments on lights 30 cm. apart the phenomenon appeared very slightly for two subjects (F. and P.), no preference was shown by one subject (H.), and the fourth subject (A.) showed a small amount of preference for the left light in the horizontal position but none for the lower light in the vertical position. The totals on all four subjects together failed entirely to show the phenomenon, the slight preference for the lower light shown by F. and P. being offset by A.'s preference for the left-hand light.

TABLE I

		Horizontal			Vertical		
		Lf	=	Rt	U	=	L
F	B	5	11	8	8	6	10
	S	7	10	7	7	8	9
H	B	7	9	8	6	12	6
	S	8	8	8	9	7	8
P	B	7	10	7	7	7	10
	S	6	9	9	9	4	11
A	B	11	6	7	9	9	6
	S	8	9	7	8	8	8
Total	B	30	36	30	30	34	32
	S	29	36	31	33	27	36

Second Apparatus, First Series
Position of Light-Cars =60cm.
Size of Light Apertures = 13mm.
Distance between Lights = 30cm.

The judgments were made on two equal lights, both light-cars being placed 60 cm. back of the apertures. The apertures were each 13 mm. in diameter. The first column at the left gives the four subjects. The next column distinguishes between size and

brightness judgments, arranged alternately. The third column gives the number of judgments in which the right and left lights were thought to be brighter or larger and the number of times they were judged equal (=). The fourth column gives the same facts for the judgments in which the lights were set vertically.

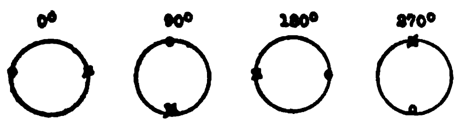
In the second set of experiments, where the subject made judgments on brightness and size by altering the position of the variable light-car and the opening in the iris diaphragm, the phenomenon wholly failed to appear in all three divergences, *i.e.* 1 m., 50 cm. and 30 cm. Neither the individual results of the different subjects nor the total results for all subjects showed any consistent tendency to place the variable light-car farther back on the tracks in the 90° position than in the others nor to place it farther forward in the 270° position, *i.e.* to underestimate the luminosity of the upper light nor to overestimate that of the lower. The same held true for the judgments of size. The average error was somewhat less in the vertical position than in the horizontal but it is impossible to interpret this positively with reference to the appearance of the phenomenon.

Discussion of Table I

In these results the phenomenon appears in only the most reduced form. The totals for all subjects show them to a very slight extent but not clearly enough to make this table of unequivocal value in demonstrating the phenomenon. In the results of the individual subjects they appeared unambiguously only once (with subject P.), and in very much reduced form even here. The slight preference for the lower light shown by subject F. was paralleled by a greater performance for the right hand light in the brightness judgments. Subject H. showed practically no tendency to favor any of the lights consistently, while subject A. gave more frequent judgments favoring the upper and left-hand lights. The results in this table, taken by themselves, are practically negative in regard to the appearance of the phenomenon in question.

TABLE II

		Intensity					
		+		—		Average	
0 position	A.	60.46		60.93		60.69	
	H.	56.07		56.65		56.36	
	F.	63.06	av. er.	56.58	av. er.	59.82	av. er.
	P.	61.16	2.19	60.17	.58	60.66	1.38
	Av.	60.19		58.58		59.38	
90 position	A.	57.81		56.33		57.07	
	H.	56.37		57.40		56.88	
	F.	59.84	av. er.	56.17	av. er.	58.00	av. er.
	P.	58.53	.14	57.54	1.04	58.03	1.00
	Av.	58.14		56.96		57.50	
180 position	A.	56.54		54.74		55.64	
	H.	57.58		56.73		57.15	
	F.	59.14	av. er.	54.67	av. er.	56.90	av. er.
	P.	57.37	.34	53.83	3.01	55.60	1.68
	Av.	57.66		54.99		56.32	
270 position	A.	57.68		55.67		56.67	
	H.	56.76		57.67		57.21	
	F.	57.78	av. er.	56.62	av. er.	57.20	av. er.
	P.	58.00	.44	57.00	1.26	57.50	.85
	Av.	57.56		56.74		57.15	



o = Standard light x = Adjustable light

		Size					
		+		—		Average	
0 position	A.	13.06		13.54		13.30	
	H.	13.63		13.35		13.49	
	F.	12.70	av. er.	13.24	av. er.	12.97	av. er.
	P.	13.40	.20	13.88	.50	13.64	.35
	Av.	13.20		13.50		13.35	
90 position	A.	13.50		13.43		13.46	
	H.	13.28		12.88		13.08	
	F.	13.08	av. er.	13.43	av. er.	13.25	av. er.
	P.	13.45	.33	13.67	.35	13.56	.34
	Av.	13.33		13.35		13.34	
180 position	A.	13.30		13.41		13.35	
	H.	13.63		12.23		13.43	
	F.	12.85	av. er.	13.38	av. er.	13.11	av. er.
	P.	13.30	.27	13.52	.14	13.41	.33
	Av.	13.27		13.14		13.33	
270 position	A.	13.00		13.36		13.18	
	H.	14.10		13.42		13.76	
	F.	12.94	av. er.	13.30	av. er.	13.12	av. er.
	P.	13.53	.39	13.80	.47	13.66	.43
	Av.	13.39		13.47		13.43	

SECOND APPARATUS, SECOND SERIES

Position of Standard Light-Car = 58cm.
Size of Standard Aperture = 13mm.
Distance between Lights = 30cm.

Explanation and Discussion of Table II

The table is entirely one of averages. The figures opposite the initials of the four subjects (in the left-hand margin) are averages of twenty judgments made by the subject. The four positions of the lights (left-hand margin) are given in the diagram. The column headed plus gives the positions of the variable light in which this was judged equal to the standard light after having been decreased from maximum luminosity by being moved backward from the position at the front of the track. That headed minus represents the judgments made by moving the light-car forward from the position at the rear of the track. The third column is made up of the averages between the + and — judgments of each subject and the figures given here are accepted as the actual equality judgment of the subject. The averages given for the three columns in each of the four positions are the averages of the four subjects. The average error is, in each case, the average error of the four subjects taken together. The same description applies to the results of size judgments. The + judgments were those in which the iris diaphragm in front of the variable light was set at its maximum opening and reduced by the subject to a size judged equal to the size of the standard light. The phenomenon in question would be considered to have appeared in these results if in the 90° position, the light-car of the variable light were consistently placed farther back than the standard light-car and farther forward in the 270° position. Comparing simply these two positions this holds true to a slight extent (57.50 cm. in the 90° position and 57.15 cm. in the 270° position) for the averages of all subjects and for the individual results of three of the subjects (A., F. and P.). The tendency to overestimate the right-hand light was, however, much stronger than the similar tendency in regard to the lower light, both for the averages of all subjects (59.38 cm. in the 0° and 56.32 cm. in the 180° position) and for the individual results of three subjects (A., F. and P.). Moreover the average error was less in the vertical

than in the horizontal position, *i.e.* the judgements were more accurate evaluations of the actual objective luminosity of the two lights in the vertical than in the horizontal position.

In the size judgments the averages of all subjects show an almost identical judgment in the 0°, 90° and 180° positions with a relative underestimation of size in the 270° position, *i.e.* the adjustable (upper in this case) light was made relatively larger than in the other positions in order to bring it to apparent equality with the size of the standard light. This is, of course, the phenomenon in question appearing in the size judgments. It appears for only two subjects, however (H. and P.) and to a very slight extent, *i.e.* the tendency to overestimate the standard light in the right position (180°) is approximately equal to the tendency to overestimate it when in the left (90°) position, whereas the tendency to overestimate this standard light is slightly greater when this is the lower light than when it is the upper one. (.43 mm. as against .34 mm.)

In the third set of experiments the results were again negative in regard to the phenomenon in question. Neither the range of positions in which the variable light was judged equal to the standard light in the horizontal and vertical positions, nor the relation of this range of positions of the variable light to the front of the track, *i.e.* the place at which this light reached its greatest luminosity for the subject, showed any evidence of the phenomenon in question. This range of positions of the adjustable light varied considerably for the different subjects and gave some indication of the effect of practice on the accuracy of these judgments. It averaged 1 cm. for subject F., 1.22 cm. for subject H. These two subjects had served in the previous set of experiments. For subjects P. and A. the average was 5.4 cm. and 2.69 cm. respectively.

The results in the fourth set of experiments were identical in general type with those of the second set. The substitution of the left for the right eye in making the observations had no appreciable effect in bringing out the phenomenon or in altering the general character of the results. The one exception to this

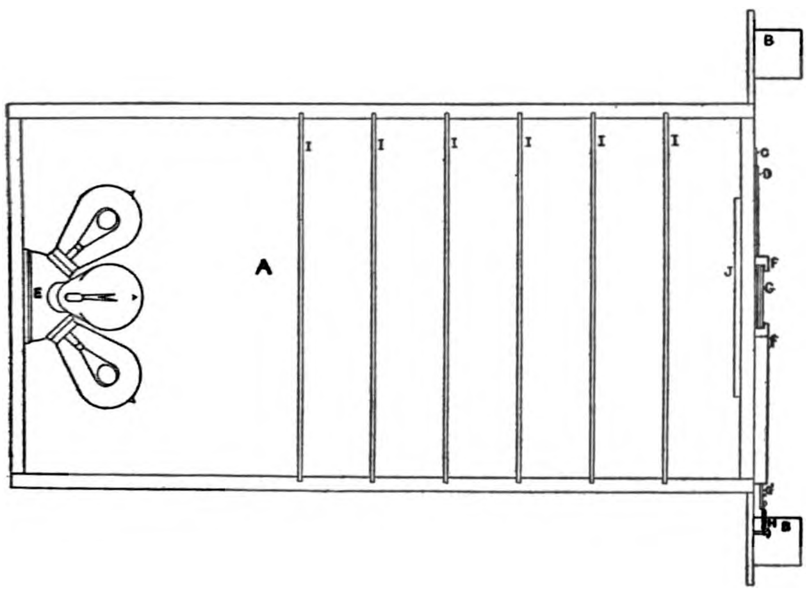
general statement was that the average error was slightly larger with the left eye than with the right—as might, perhaps, have been expected since the right eye had been used in all the other experiments with this apparatus.

The results of the experiments made with indirect vision (5th set), both in the series with a central fixation point and in that with outside fixation points, failed entirely to bring out the phenomenon. The size judgments were either reported as impossible throughout the series or were uniformly reported as equal. These two types of report apparently stood for the same sort of judgment, as indicated in the introspective accounts of the different subjects. The judgments of brightness were somewhat more erratic than was the case in the experiments with direct vision, one of the lights frequently being strongly favored, but the judgments failed to show any consistent preference for one light in either the horizontal or vertical position. This was more noticeable when the fixation point was between the lights than when it was at the side and was correlated with a greater tendency of the eye to wander from its fixation in these central fixation judgments. In spite of the occasional and relatively strong preferences for one of the two lights, the judgments in this entire set of experiments were much more predominantly judgments of equality than in the series with direct vision and were, on the whole, much more accurate evaluations of the actual objective brightness of the two lights.

The only fact that appeared in connection with the sixth set of experiments, in which the judgments on size and brightness were made separately (the lights remaining equal in one factor while the other was altered by the subject) was that the evaluations of the lights in both brightness and size were more accurate than in the earlier series where both factors were judged at once. This would naturally be expected, in the nature of the case, as the two factors had shown a mutually compensatory effect in the previous judgments. The particular phenomenon in question was quite as completely absent in this as in the previous experiments.

The judgments with this second form of apparatus were, of course, extra foveal in all cases, *i.e.* the distance between the two object lights was always such that both could not be simultaneously fixated in foveal vision. This fact forms one of the main reasons for regarding these particular phenomenon as confined exclusively to foveal vision. This will be discussed in detail at a later point.

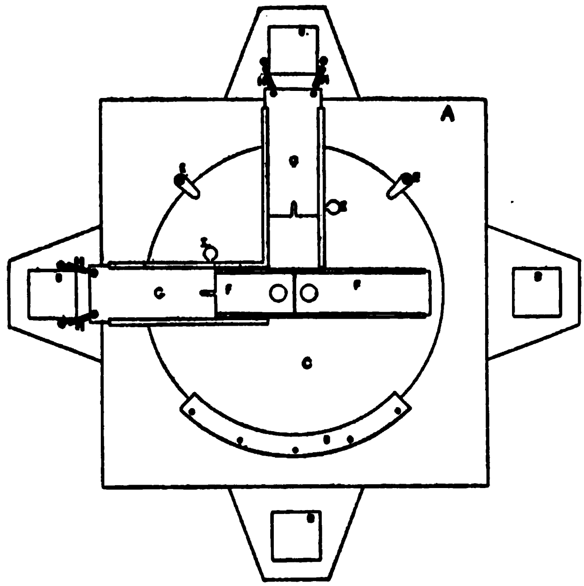
FIGURE 5



THIRD APPARATUS

A—Main light box
BB—Right and left pinhole light-boxes
C—Brass disk
D—Brass slot for aperture slides
E—4-lamp rosette
FF—Slots for exposure shutters
G—Vertical exposure shutter
G′—Horizontal exposure shutter
H—Coiled spring for horizontal exposure shutter
III—Ground glass diffusion screens
J—Slot for colored gelatine strips
The upper and lower pinhole light-boxes are not shown.

FIGURE 6



THIRD APPARATUS

A—Main light-box
BBBB—Pinhole light-boxes for eccentric fixation.
C—Brass disk
D—Brass slot in which C revolves
EE—Lugs for holding disk tight against front of light-box
FF—Brass aperture slides
GG—Horizontal and vertical exposure shutters
HHHH—Coiled wire springs for moving shutters GG
II—Release buttons for shutters GG

THIRD FORM OF APPARATUS

Description

In this form two objective light surfaces were shown, as in the second type of apparatus. The source of light, however, was unitary and the openings alone were rotated. The apparatus consisted of a light-tight, rectangular, wooden box, 92 cm. long and 48 cm. square. At the center of the rear wall of the box was mounted a "four-way" electric light rosette supplied with four 32 candlepower lamps. This was so placed that one lamp each pointed directly upwards, downwards, right and left. They were also so adjusted that the filaments were identially placed with reference to the front of the box. A circular opening, 35 cm. in diameter, was cut in the front wall of the box, concentric with this wall. In front of this, and fitting tightly against the box was a brass disk, 37 cm. in diameter. This was held in place, concentric with the opening by a metal groove, running around the lower third of the disk, into which it fitted. A strip of black velvet, running around the edge of the opening, on the front of the box, made a light-tight joint. The disk could be rotated without removal from the groove or it could be removed from the groove by turning a pair of wing screws at the top. A slot 29 cm. long and 8 cm. wide was cut concentric with the disk. On both faces of the disk, 1 cm. from the edges of the slot and paralleling the same, metal grooves were soldered. Brass slides, 10 cm. wide and of varying lengths, were made to run in the grooves on the front of the disk. These slides each contained one circular opening, varying in size from 1 to 4 cm. diameter. The openings were cut so that the edge came 1 mm. from the end of the slide. Two of these slides could be used with the aperture ends turned toward the center of the disk. By using solid slides of different lengths between them and overlapping these 1 mm. on to each of the aperture slides, any required dis-

tance between the inner edges of the two lights could be obtained from 1 mm. to 25 cm. Two openings differing in diameter by .5 mm. or more were used to produce unequal pairs of lights. Inequality in intensity was produced by the use of diffusion screens which slid into the grooves on the back of the disk. When unequal intensities were desired, unequal numbers of these screens were put behind the two individual openings. The inside of the light box also contained grooves for large ground glass diffusion screens, six of which were used at different distances from the light cluster. The inside of the box was given four coats of white enamel paint. The sides and back thus served as reflectors. The surface of the back wall was uniform throughout and the sides were identical in area and character of reflecting surface. The four lamps were connected in parallel with a 220-volt, 15-ampere circuit from the University power house which was very constant after 5 P. M. New lamps were substituted after the old ones had burned for one fourth of their estimated kilowatt-hour life. In one of the control series with this apparatus four small light-boxes, similar to those used in the second apparatus, were used for eccentric fixation. These were placed directly above, below, to right and left of the center of the disk and 30 cm. distant. Wooden slides, running in grooves, were also added to the front of the box for use in the judgments with indirect vision. One of these projected over the disk from the left side, the other from above. They both extended 4 cm. beyond the center of the disk. By releasing a catch either one could be shot back, exposing the center of the disk, in something under one tenth of a second. In the center of part of the solid brass slides, used to separate the aperture slides, a small pinhole was drilled through which the light from behind appeared. A slot about 2 mm. wide was cut in the inner end of each of the wooden slides so as to allow this small spot light to be seen both while the screen was set, covering the two large lights, and while it was being shot back to expose these. The horizontal slide was used to expose the lights in the vertical positions and the vertical slide the lights in the horizontal positions. By this

method a permanent fixation was given and the lights were exposed almost instantaneously and wholly simultaneously. The position and arrangement of the subject's chair was the same as in the second form of apparatus except for the absence of the control wheel and lever.

Procedure

First Set of Experiments (Main Set)

In the main set of experiments with this apparatus the procedure, as far as concerned the subject, was identical with that in the first set with the second apparatus (see page 17). Simple judgments of equality or inequality in size and luminosity were made between two lights which were exposed simultaneously and which remained constant during the judgment. The subject exercised no control over either one of them. The differences in procedure (affecting the operator) were merely such as were incident to the new method of changing the position, relative size and intensity, separation, etc. of the lights in this form of apparatus. The instructions to the subject were also identical with those given in the first set with the second apparatus. The interval between judgments was shorter than in any of the series with the second form of apparatus, due to the greater ease with which the positions of the lights could be changed in this apparatus. The time averaged 30 seconds between judgments with an additional period of 3 minutes between series of eight judgments. The length of the sittings averaged between 40 and 45 minutes and 30 exposures were given. Three sizes of aperture were used for the main set of results. These were 1 cm., 2 cm. and 4 cm. in diameter. Two of these were larger and one smaller than the standard aperture used for the main set of experiments with the second apparatus. (13 mm.) Four colors were used. (Yellow, red, green, white.) Twice as many judgments were taken with the yellow as with any of the other colors as the yellow lights seemed to approximate most nearly to the conditions of the astronomical phenomena in question. Varying numbers of screens were used with the different colors to equate

them in brightness. The lights, with all four colors, were equated in brightness with the standard light of the second apparatus placed at 60 cm. (the position of the standard light used for the main set of experiments with that apparatus). The difficulty in obtaining a blue of equal saturation and brightness with the other colors prevented the use of this color. The lights were shown in five different divergences. These were 0 and 13 cm., forming the two extremes, and three divergences equal respectively to ½ the diameter of the aperture used, to the diameter of the aperture and to twice the diameter of the aperture. The largest of these divergences was smaller than the smallest divergence possible with the second form of apparatus.

Sets of Control Experiments

These were made for the purpose of bringing out the effect of certain modifications of the method employed in the main set of experiments with this apparatus, *i.e.* indirect vision, binocular vision, oblique positions of the object lights instead of the vertical-horizontal arrangement, etc.

Throughout the control series only three colors were used instead of four as in the main set of experiments with this apparatus. The results for the white light so closely approximated those for the yellow that the white was omitted for this series. The 2 cm. aperture alone was used. This had uniformly shown the phenomenon in question so much more clearly than the 1 and 4 cm. apertures that it was decided that the results of the control series would appear more clearly with this than with the other openings.

Second Set of Experiments (Control I)

In this series the procedure, for both subject and operator, was identical with that in the main series with this apparatus except that the lights were shown in oblique positions instead of in the horizontal and vertical as in all previous series. This necessitated a slightly different form for reporting judgments and these were given as upper-right, upper-left, lower-right and lower-left.

Third Set of Experiments (Control II)

Here the one variation on the main series was that the judgments were made in binocular instead of monocular vision. Otherwise the procedure for subject and operator alike was identical with the main series with this apparatus.

Fourth Set of Experiments (Control III)

This was also identical with the main series except for one variation. In this case the difference was in the eye used—here the left eye, instead of the right as in the previous experiments with this apparatus, was used.

Fifth Set of Experiments (Control IV)

In this set the permanent central fixation point was used. The procedure was as follows. The subject's shutter was dropped; the lamp cluster in the light box was switched on; the disk, with the aperture slides adjusted, was put in the desired position; one of the exposure shutters was drawn over the disk and set; (see description of apparatus, page 36) the subject's eye-piece shutter was raised and he fixated the pinhole light visible through the small slot in the end of the exposure shutter: the ready signal was given, the catch of the exposure shutter released and the lights exposed. After making his judgment the subject's shutter was dropped, the lights shifted to another position and the process repeated. Aside from this introduction of a central fixation point which was visible before the lights were shown, this series was like the main set with this apparatus.

Instructions to Subjects

The subjects were instructed to hold the fixation of the small light steadily both before and during the exposure of the two object lights and he was asked to report any failure to carry out this instruction.

The object of this control series was to determine whether primacy, in the fixation of one light, bore any definite relation to the tendency to overestimate this light. Without the central spot

for fixation before the object lights were exposed it was impossible to determine with any accuracy, which of the two object lights was first focused.

Sixth Set of Experiments (Control V)

The object of this control was to determine the extent to which the phenomenon in question, which had appeared strikingly in the main series with direct vision, might occur with indirect vision.

In this series the subject's procedure and the instructions to the subject were identical with those in the series of indirect-vision judgments with the second apparatus (with fixation lights 60 cm. from the central axis). (See Procedure, page 23.) There was in this series, however, no central fixation point placed directly between the lights. This was omitted because, owing to the relatively small distance between the lights, fixation of a spot light placed between them did not bring them into genuine indirect vision. The only variation in the operator's procedure with this apparatus was such as inhered in the differences between this form and the second apparatus, *i.e.* the manner of changing the position, separation and relative size and intensity of the two lights, method of exposing the lights by a single shutter sliding over both lights instead of the double shutter of the second form, etc.

Seventh Set of Experiments (Control VI)

In this series the procedure was identical, for both subject and operator, with that of the main series. The one difference was in the amount of separation of the two lights. The object was to determine approximately the amount of separation of the lights at which the phenomena under examination ceased to be unquestionably present. The different distances used between the lights were 8, 12, 18 and 24 cm. making the divergence respectively 4, 6, 9 and 12 times the diameter of the light.

Eighth Set of Experiments (*Control VII*)

The object of this series was to secure some objective evaluation for the overestimation of the lower of two vertical lights which, in the horizontal position, were regarded as equal, as well as some objective measure of the amount of difference in luminosity which would be overlooked in the horizontal and in the vertical position. The procedure of the subject was the same as in the main series with this apparatus. The only difference in the operator's procedure was in the use of unequal numbers of screens behind the two apertures.

Subjects

In the experiments with the third form of apparatus four subjects were again used. Dr. M. H. S. Hayes, Dr. M. R. Fernald, Dr. E. M. Chamberlain and Mr. F. A. C. Perrin (F.P.). All were graduate students in the Psychological Laboratory and all were competent observers and introspectors. Unfortunately it was not possible to have the same group of subjects throughout the experiments with the three forms of apparatus. H. and F. served throughout the entire series, C. acted as subject with the first and with the third form of apparatus, while F. P. served only for the third series. Subject F. P. did not wear glasses and reported completely normal vision. No difference in the visual acuity of the two eyes was known to exist or discovered in reading tests.

The large amount of practice which H. and F. had had in the two previous series makes their results not wholly comparable with those of the other two subjects, and especially with those of F. P. All of the subjects had difficulty with those indirect vision judgments in which the two object lights were very close together; especially those in which the lights were 1 cm. apart. In these cases judgments on size were generally reported as impossible. A third form of judgment, in addition to those on size and luminosity, which was most persistent with F. P., was frequently added during the work with this form of apparatus. The lights appeared as differently placed in the third dimension.

The larger and brighter light was generally regarded as the nearer, but this relation was by no means constant and even a light which was judged to be both smaller and dimmer was occasionally thought to be nearer.

Results

First Set of Experiments (Main Set)

In these experiments with the third form of apparatus the phenomenon appear very strikingly and consistently throughout the results of each of the four subjects as well as throughout the total results of all subjects taken together. It appears clearly in each of the five divergences taken separately, and strikingly in all but the two extreme divergences (O and 13 cm.). It appears very noticeably in each of the four colors considered separately and with each of the three apertures used. While individual judgments not infrequently favor the right or left light as well as the lower, or actually favor the upper instead of the lower; and while the judgments on one color or aperture with a particular divergence occasionally fail to show the phenomena, show the reverse preference for the upper light, or show an equal or greater preference for one of the lights in the horizontal position, yet this is never true in the totals for any aperture, color or divergence.

No one of the subjects has, of course, shown an exact equality of judgments favoring the right and left lights in the horizontal position, but the difference in these judgments for subjects F. and H. is so slight as to be practically negligible and when taken in connection with the very large number of positive judgments of equality given for this position, the relatively small number of such judgments in the vertical position, and the great preponderance of judgments favoring the lower light, it shows the phenomenon in a very striking manner with these two subjects. The phenomena are less apparent with the other two subjects, with whom the preference for the lower light is paralleled by a distinct preference for the left-hand light. This latter preference never, however, equals or closely approximates

the former in any of the sets of totals except in the 13 cm. divergence totals. The effect of practice in bringing out the phenomenon is at least indirectly shown in the results of the four subjects. The two subjects with whom it appears most clearly and most consistently, H. and F., are the ones who have acted as subjects for all the previous series with the different forms of apparatus, while the subject with whom it appears least clearly, P, has acted in none of the previous experiments. The possibility of suggestion in this is obviated by the fact that all of the subjects have been kept in ignorance of everything save the general nature of the problem. None of them has been aware that the lower light has been preponderantly judged brighter in other fields of work; none of them has had any knowledge as to whether the two lights shown in any particular case were objectively equal or unequal.

The judgments on brightness have consistently shown the phenomenon more strikingly than those on size. This is not to be correlated with the order of making or giving the judgments as this has varied continually with all subjects. The negative judgments (Tables 18-22) have most frequently concerned the size factor, *i.e.* a distinct difference in brightness was recorded but no decision could be made as to a difference in size, though the subject was almost equally unable to say that the two lights were certainly and undoubtedly equal in size. Moreover, these judgments have most frequently occurred where the lights were thought to be only slightly different in brightness. Where the brightness judgment was one of marked inequality, the size judgment generally showed a parallel preference. The percentage of judgments where one light was accepted as larger and the other as brighter is so small as to be almost negligible except in the case of subject P, with whom they are relatively numerous. This fact, taken together with the statement in regard to the negative judgments, the uniformly larger number of judgments of equality for size, and the less noticeable preference for the lower light in the size judgments, seems to indicate that the phenomenon in question is concerned chiefly, if not solely,

with the brightness factor and that whatever evidence of it appears in the size judgments is due to the tendency to regard the brighter light as also the larger.

The tendency of the phenomenon to appear most frequently and most clearly in the 2 cm. aperture is decidedly striking in the results of all four subjects. This fact might be interpreted as an effect of practice, as it occurs more conspicuously with subjects F. and H. than with A. and P., but this aperture is less like that used in the main set of experiments with apparatus 2 than is the 1 cm. aperture of this apparatus. The introspection of the different subjects indicates that these medium sized lights were *"more easy to judge."* Compared with the smaller lights they showed less irradiation—always a somewhat distracting factor where it appeared markedly—while in comparison with the larger lights they were more easily "focused together," with less tendency of the eye to move over the surface of each light. In the case of the larger lights it was most frequently reported that one or both lights did not appear uniformly bright over the entire surface, a factor making judgment of relative luminosity difficult. Visual associations and partial illusions were most frequently reported in judgments on the largest lights, such as "automobile head-lights," "cat's eyes," "brownies," etc. While these associative experiences sometimes strongly influenced the judgments, they also interfered with the judgments in many cases.

The tendency of the phenomenon to appear most frequently with the red and green lights seems to have been in part, at least, correlated with the greater saturation of these two colors. The remark, "it looks more saturated, so I suppose it is less bright" was quite frequently made with regard to the red and green. and particularly with reference to the former, while it was made with much less frequency in regard to the yellow and white. The preponderance of the phenomenon with the red, as against the other colors, is by no means as striking as this preponderance with the 2 cm. aperture as compared with the other apertures. The size of the opening has apparently a greater effect on the

appearance of the phenomenon than the color of the light. The red and green light were more frequently referred to as "pleasanter" than were the others, apparently in virtue of their greater saturation. This was particularly true of the red. The white was reported as having the greatest amount of irradiation and the red the least, which may have been a determining factor in the relative importance of the phenomenon with the different colors. The appearance of the phenomenon in the different colors showed less uniformity with the different subjects than did its relative importance in the different apertures and divergences; the color factor, that is, appeared to be more an individual characteristic of the different subjects and less evidently a persistent factor of the phenomenon than did the other factors of size of aperture and separation of the lights.

The relative importance of the phenomenon in the five different divergences in which the lights were shown was more uniform than in the four different colors. The 13 cm. divergence invariably showed them least clearly and the O divergence to the next smallest extent. As between the three other divergences there was less uniformity in the frequency with which the phenomenon appeared but, on the whole, the divergence equal to the light diameter showed them most clearly. The introspective accounts indicated that, as in the case of the medium sized aperture, the lights shown with this divergence were "easier to judge" and that those shown with the o and 13 cm. divergence were the most difficult. In the case of the O divergence the two lights tended to fuse and become difficult to distinguish clearly. Where there was a marked irradiation from the two lights in this position, this tended further to impede the judgment, in both size and brightness. In the 13 cm. divergence the lights were far enough apart so that a distinct eye movement was necessary in order to compare them. The comparison became then one between a light seen in direct vision and one seen in indirect vision. In the cases of the medium divergences it was possible to take in both lights in direct vision without, on the other hand, having them fuse together.

In the following tables of results for the main series of experiments with the 3d apparatus, two sets of totals are given *i.e.* one including the 13 cm. divergence results and one exclusive of these results. The results are given in this way because the 13 cm. divergence is really intermediate between the other divergences used with this apparatus and the smallest divergence used with the second apparatus. The phenomenon appeared much less strikingly in the 13 cm. results than in the results with the smaller divergences and it's unambiguous appearance with these smaller divergences is more clearly seen when the 13 cm. results are left out.

Third Apparatus, first series. Results with three apertures, five divergences and four colors given separately

TABLE III

INDIVIDUAL RESULTS—SUBJECT F.

Diameter of lights

Distance between lights	Judgm't on	Color	1 cm.						2 cm.						4 cm.					
			Horiz			Vert			Horiz			Vert			Horiz			Vert		
			Lf	=	Rt	Up	=	Lw	Lf	=	Rt	Up	=	Lw	Lf	=	Rt	Up	=	Lw
0 cm.	Br.	Y	0	6	2	0	4	4	6	2	0	0	4	4	4	4	0	2	2	4
		R	0	4	0	1	0	3	2	2	0	0	0	4	0	2	2	0	2	2
		G	2	2	0	1	0	3	0	2	2	2	0	2	4	0	0	0	2	2
		W	0	1	3	1	1	2	0	3	1	1	0	3	4	0	0	0	2	2
	Size	Y	1	3	4	2	2	4	6	0	2	1	3	4	2	2	4	3	3	2
		R	0	3	1	0	2	2	1	1	2	1	1	2	2	1	1	1	2	1
		G	2	2	0	1	0	3	0	2	2	2	0	2	2	0	2	0	4	0
		W	1	0	3	1	2	1	0	2	2	0	0	4	3	0	1	0	2	2
½ diameter of light	Br.	Y	2	4	2	1	0	7	0	8	0	1	0	7	1	6	1	2	0	6
		R	2	2	0	1	0	3	1	3	0	0	0	4	1	2	1	1	0	3
		G	0	4	0	1	0	3	0	3	1	0	0	4	1	2	1	0	0	4
		W	1	3	0	1	0	3	0	2	2	1	0	3	0	3	1	0	0	4
	Size	Y	4	2	2	2	2	4	1	7	0	2	3	3	3	3	2	2	1	5
		R	1	2	1	1	0	3	1	3	0	0	0	4	1	1	2	1	2	1
		G	0	4	0	1	2	1	0	3	1	0	0	4	2	1	1	0	2	2
		W	1	3	0	1	1	2	1	1	2	0	2	2	1	3	0	1	1	2
= diameter of light	Br.	Y	2	2	4	0	2	6	1	7	0	0	0	8	1	5	2	0	1	7
		R	0	2	2	0	0	4	0	4	0	0	0	4	1	2	1	0	1	3
		G	1	3	0	0	0	4	0	4	0	0	0	4	0	4	0	0	1	3
		W	1	3	0	1	0	3	1	3	0	0	0	4	0	2	2	0	1	3
	Size	Y	2	2	4	2	2	4	1	6	1	0	3	5	1	5	2	0	3	5
		R	1	3	0	2	0	2	0	4	0	0	2	2	1	2	1	2	1	1
		G	1	3	0	0	0	4	1	3	0	0	0	4	0	0	4	0	2	2
		W	1	1	2	0	4	0	0	4	0	0	0	4	1	2	1	0	0	4
2 × diameter of light	Br.	Y	0	8	0	0	3	5	0	4	4	0	2	6	0	0	8	4	0	4
		R	0	4	0	0	2	2	0	2	2	0	0	4	0	3	1	0	0	4
		G	1	2	1	0	2	2	0	4	0	0	1	3	1	3	0	0	2	2
		W	1	2	1	0	1	3	0	4	0	0	1	3	2	2	0	1	2	1
	Size	Y	0	8	0	3	3	2	0	6	2	1	3	4	5	1	2	4	0	4
		R	0	4	0	1	1	2	2	1	1	0	0	4	0	4	0	2	2	0
		G	1	2	1	0	1	3	0	4	0	2	1	1	0	4	0	2	2	0
		W	0	0	4	2	0	2	1	3	0	1	1	2	1	3	0	2	0	2
13 cm.	Br.	Y	2	1	5	2	2	4	4	4	0	0	3	5	2	2	4	0	2	6
		R	2	1	1	0	0	4	0	4	0	0	1	3	1	2	1	2	2	0
		G	1	1	2	0	1	3	0	0	4	0	0	4	2	1	1	2	2	0
		W	2	1	1	1	1	2	0	1	3	0	0	4	3	1	0	3	1	0
	Size	Y	1	5	2	1	5	2	1	2	5	3	5	0	4	3	1	0	2	6
		R	1	1	2	0	0	4	0	4	0	0	2	2	2	0	2	1	3	0
		G	1	1	2	0	2	2	1	3	0	1	3	0	0	2	2	1	1	2
		W	2	1	1	0	4	0	0	1	3	0	0	4	1	2	1	1	3	0

TABLE IV

INDIVIDUAL RESULTS—SUBJECT H.

Distance between lights	Judgm'nt on	Color	Diameter of lights: 1 cm. Horiz Lf = Rt			1 cm. Vert Up = Lw			2 cm. Horiz Lf = Rt			2 cm. Vert Up = Lw			4 cm. Horiz Lf = Rt			4 cm. Vert Up = Lw		
0 cm.	Br.	Y	2	4	2	2	2	4	2	4	2	2	0	6	2	6	0	4	0	4
		R	2	2	0	0	2	2	0	4	0	0	0	4	0	2	2	1	1	2
		G	2	2	0	0	0	4	0	2	2	0	2	2	0	4	0	0	2	2
		W	0	0	4	1	0	3	1	3	0	0	1	3	0	0	4	0	2	2
	Size	Y	3	3	2	0	2	6	2	4	2	0	2	6	2	5	1	4	0	4
		R	2	2	0	1	1	2	1	2	1	2	0	2	1	0	3	1	1	2
		G	2	2	0	0	2	2	2	0	2	0	2	2	3	1	0	0	4	0
		W	1	1	2	1	2	1	1	3	0	1	1	2	1	2	1	0	3	1
½ diameter of light	Br.	Y	3	5	0	0	2	6	0	8	0	0	1	7	3	2	3	0	0	8
		R	0	4	0	0	0	4	0	4	0	0	0	4	2	2	0	0	1	3
		G	2	0	2	0	0	4	0	4	0	0	0	4	0	4	0	0	2	2
		W	0	4	0	0	2	2	2	1	1	0	2	2	0	2	2	2	0	2
	Size	Y	3	4	1	2	2	4	2	6	0	1	0	7	5	0	3	3	0	5
		R	1	3	0	0	1	3	0	4	0	0	0	4	2	2	0	0	0	4
		G	2	0	2	0	4	0	0	3	1	0	2	2	0	4	0	1	3	0
		W	0	4	0	0	2	2	2	1	1	0	2	2	1	2	1	0	1	3
= diameter of light	Br.	Y	4	4	0	0	2	6	2	6	0	0	0	8	0	7	1	0	2	6
		R	0	3	1	0	0	4	0	4	0	0	0	4	0	2	2	0	0	4
		G	0	4	0	0	0	4	0	4	0	0	0	4	2	2	0	0	0	4
		W	0	3	1	0	0	4	0	4	0	0	0	4	1	1	2	0	2	2
	Size	Y	3	4	1	0	4	4	2	4	2	2	0	6	0	5	3	2	2	4
		R	0	4	0	0	0	4	0	4	0	0	0	4	0	2	2	0	0	4
		G	0	2	2	0	0	4	2	2	0	0	0	4	2	0	2	0	0	4
		W	0	3	1	0	2	2	0	4	0	0	0	4	0	1	3	0	2	2
2 × diameter of light	Br.	Y	0	4	4	2	4	2	2	4	2	0	4	4	4	0	4	0	4	4
		R	0	4	0	0	0	4	0	4	0	0	0	4	0	3	1	0	1	3
		G	1	3	0	0	1	3	0	4	0	0	0	4	0	2	2	2	0	2
		W	2	2	0	0	2	2	0	4	0	0	1	3	1	1	2	1	3	0
	Size	Y	0	4	4	1	4	3	1	5	2	2	4	2	2	2	4	0	6	2
		R	2	2	0	3	0	1	0	4	0	0	0	4	2	1	1	0	1	3
		G	0	4	0	0	1	3	0	4	0	0	0	4	0	3	1	1	1	2
		W	2	1	1	0	0	4	0	2	2	0	1	3	1	1	2	3	1	0
13 cm.	Br.	Y	2	0	6	3	2	3	3	2	3	2	4	2	3	3	2	2	2	4
		R	0	2	2	0	2	2	2	1	1	2	0	2	0	2	2	1	0	3
		G	2	0	2	1	2	1	2	0	2	0	0	4	3	1	0	1	2	1
		W	3	1	0	1	0	3	2	0	2	1	2	1	3	0	1	3	1	0
	Size	Y	3	0	5	4	1	3	3	2	3	2	4	2	4	4	0	2	2	4
		R	1	2	1	0	2	2	2	1	1	2	0	2	1	1	2	1	2	1
		G	2	0	2	2	2	0	2	0	2	0	0	4	0	3	1	2	2	0
		W	2	2	0	0	0	4	0	2	2	0	2	2	3	0	1	3	1	0

TABLE V

Individual Results—Subject A.

Distance between lights	Judgm't on	Color	Diameter of lights: 1 cm. Horiz Lf	=	Rt	Vert Up	=	Lw	2 cm. Horiz Lf	=	Rt	Vert Up	=	Lw	4 cm. Horiz Lf	=	Rt	Vert Up	=	Lw
0 cm.	Br.	Y	4	2	2	2	0	6	5	0	3	4	0	4	4	1	3	2	0	1
		R	0	2	2	0	0	4	2	0	2	2	0	2	0	4	0	0	2	2
		G	1	0	3	0	4	0	1	3	0	0	0	4	2	0	2	0	0	4
		W	2	0	2	3	0	1	2	0	2	0	0	4	4	0	0	2	2	0
	Size	Y	5	2	1	2	2	4	4	1	3	3	0	5	4	2	2	3	0	5
		R	1	2	1	0	1	3	2	0	2	2	0	2	0	4	0	0	2	2
		G	2	0	2	0	2	2	1	2	1	0	0	4	2	1	1	0	1	3
		W	1	0	3	2	1	1	4	0	0	0	1	3	2	0	2	2	1	1
½ diameter of light	Br.	Y	2	2	4	3	0	5	2	2	4	2	0	6	7	1	0	0	0	8
		R	4	0	0	0	0	4	4	0	0	0	0	4	0	0	4	0	0	4
		G	2	1	1	0	0	4	3	0	1	0	0	4	0	2	2	0	0	4
		W	1	0	3	2	0	2	1	0	3	0	0	4	0	2	2	1	0	3
	Size	Y	2	3	3	2	0	6	2	2	4	2	0	6	6	2	0	1	2	5
		R	4	0	0	0	0	4	3	1	0	0	0	4	0	1	3	0	0	4
		G	2	0	2	0	0	4	2	1	1	1	1	2	1	1	2	0	0	4
		W	2	0	2	2	0	2	1	0	3	0	0	4	0	4	0	3	0	1
= diameter of light	Br.	Y	2	2	4	0	0	8	2	0	6	1	0	7	7	0	1	2	0	6
		R	2	0	2	0	0	4	0	2	2	0	0	4	1	0	3	0	0	4
		G	2	0	2	0	0	4	3	0	1	0	0	4	2	0	2	1	0	3
		W	4	0	0	0	0	4	4	0	0	0	0	4	1	0	3	1	0	3
	Size	Y	2	1	5	2	0	6	2	1	5	2	0	6	5	0	3	4	0	4
		R	1	0	3	0	1	3	0	1	3	0	0	4	1	1	2	0	0	4
		G	2	0	2	1	0	3	0	3	1	0	1	3	1	1	2	1	0	3
		W	4	0	0	0	2	2	2	2	0	0	0	4	1	0	3	1	0	3
2 × diameter of light	Br.	Y	5	3	0	2	0	6	4	1	3	0	1	7	1	0	7	2	1	5
		R	2	0	2	0	0	4	2	2	0	0	0	4	0	4	0	0	0	4
		G	2	0	2	0	0	4	0	2	2	0	0	4	2	2	0	1	0	3
		W	3	0	1	0	0	4	2	0	2	3	0	1	2	0	2	2	0	2
	Size	Y	3	4	1	1	0	7	4	1	3	1	0	7	2	2	4	1	2	5
		R	2	0	2	1	0	3	1	3	0	0	0	4	1	3	0	0	0	4
		G	0	2	2	0	0	4	1	1	2	1	0	3	2	2	0	0	1	3
		W	2	1	1	1	0	3	2	0	2	2	1	1	2	0	2	1	0	3
13 cm.	Br.	Y	2	2	4	4	2	2	2	4	2	0	4	4	4	2	2	3	0	5
		R	0	4	0	2	0	2	2	0	2	3	1	0	1	2	1	0	4	0
		G	0	2	2	1	3	0	2	2	0	0	2	2	0	4	0	0	4	0
		W	2	1	1	0	2	2	0	3	1	0	0	4	2	2	0	2	0	2
	Size	Y	2	2	4	4	2	2	4	2	2	2	4	2	4	2	2	3	0	5
		R	0	3	1	1	1	2	1	1	2	3	0	1	2	1	1	1	3	0
		G	1	1	2	1	3	0	2	2	0	0	2	2	0	3	1	2	2	0
		W	3	1	0	0	1	3	0	3	1	0	1	3	2	2	0	1	1	2

TABLE VI

INDIVIDUAL RESULTS—SUBJECT P.

Diameter of lights

Distance between lights	Judgm'nt on	Color	1 cm. Horiz Lf	=	Rt	1 cm. Vert Up	=	Lw	2 cm. Horiz Lf	=	Rt	2 cm. Vert Up	=	Lw	4 cm. Horiz Lf	=	Rt	4 cm. Vert Up	=	Lw
0 cm.	Br.	Y	4	0	4	0	4	4	4	4	0	4	0	4	0	6	2	2	2	4
		R	2	0	2	0	0	4	2	2	0	0	1	3	2	2	0	2	0	2
		G	2	0	2	0	2	2	2	0	2	2	0	2	2	2	0	0	2	2
		W	2	1	1	1	1	2	1	2	1	1	0	3	2	1	1	1	1	2
	Size	Y	4	0	4	1	4	3	4	4	0	2	0	6	0	4	4	2	2	4
		R	2	0	2	0	3	1	0	4	0	0	1	3	2	2	0	2	0	2
		G	2	0	2	0	2	2	2	1	1	2	0	2	2	1	1	1	2	1
		W	2	1	1	1	2	1	2	1	1	1	0	3	3	0	1	1	1	2
½ diameter of light	Br.	Y	3	5	0	2	2	4	2	4	2	2	2	4	2	2	4	2	2	4
		R	0	2	2	1	0	3	2	2	0	0	0	4	2	0	2	0	0	4
		G	0	4	0	0	2	2	2	2	0	0	0	4	1	2	1	0	2	2
		W	2	1	1	1	1	2	0	2	2	2	0	2	2	1	1	0	2	2
	Size	Y	5	3	0	2	4	2	2	3	3	2	2	4	2	2	4	2	3	3
		R	1	1	2	1	0	3	2	1	1	0	0	4	2	1	1	0	2	2
		G	0	3	1	1	3	0	1	2	1	0	0	4	2	2	0	0	2	2
		W	2	0	2	1	1	2	0	0	4	2	1	1	1	2	1	0	2	2
= diameter of light	Br.	Y	3	5	0	2	2	4	3	3	2	4	0	4	4	2	2	2	2	4
		R	2	0	2	2	0	2	0	4	0	0	0	4	0	4	0	0	0	4
		G	2	0	2	0	0	4	2	2	0	0	0	4	2	0	2	0	2	2
		W	1	1	2	0	1	3	0	4	0	0	1	3	2	0	2	2	0	2
	Size	Y	4	4	0	2	3	3	3	1	4	5	0	3	4	3	1	2	2	4
		R	1	1	2	2	2	0	0	2	2	0	0	4	1	3	0	0	0	4
		G	2	1	1	0	0	4	2	2	0	0	2	2	2	0	2	0	1	3
		W	0	2	2	0	0	4	2	2	0	1	0	3	2	0	2	2	1	1
2 × diameter of light	Br.	Y	4	2	2	2	2	4	0	2	6	1	0	7	4	4	0	2	0	6
		R	0	2	2	0	0	4	4	0	0	0	0	4	2	2	0	0	0	4
		G	0	2	2	1	1	2	2	2	0	2	0	2	3	0	1	0	1	3
		W	4	0	0	2	2	0	3	0	1	0	0	4	0	0	4	0	2	2
	Size	Y	2	4	2	1	2	5	2	0	6	0	0	8	6	2	0	3	0	5
		R	2	0	2	1	0	3	2	2	0	0	2	2	0	2	2	1	0	3
		G	1	2	1	0	1	3	4	0	0	2	1	1	2	0	2	0	0	4
		W	4	0	0	2	1	1	1	2	1	0	1	3	0	0	4	2	2	0
13 cm.	Br.	Y	2	4	2	4	2	2	3	4	1	2	2	4	0	6	2	2	6	0
		R	2	2	0	1	0	3	2	0	2	0	2	2	1	1	2	0	2	2
		G	2	2	0	2	0	2	0	2	2	0	1	3	0	4	0	2	0	2
		W	1	3	0	0	2	2	0	4	0	2	1	1	2	2	0	3	0	1
	Size	Y	1	4	3	4	0	4	2	5	1	2	4	2	1	5	2	3	5	0
		R	1	2	1	0	1	3	3	0	1	1	1	2	1	2	1	1	1	2
		G	1	3	0	3	0	1	1	2	1	0	1	3	1	3	0	2	0	2
		W	1	3	0	1	1	2	0	4	0	1	2	1	1	2	1	2	1	1

TABLE VII

RESULTS FOR ALL FOUR SUBJECTS TOTALED

Diameter of lights

Distance between lights	Judgm'nt on	Color	1 cm. Horiz			1 cm. Vert			2 cm. Horiz			2 cm. Vert			4 cm. Horiz			4 cm. Vert		
			Lf	=	Rt	Up	=	Lw	Lf	=	Rt	Up	=	Lw	Lf	=	Rt	Up	=	Lw
0 cm.	Br.	Y	10	12	10	4	10	14	17	10	5	10	4	18	10	17	5	10	4	13
		R	4	8	4	1	2	13	6	8	2	2	1	13	2	10	4	3	5	8
		G	7	4	5	1	6	9	3	7	6	4	2	10	8	6	2	0	6	10
		W	4	2	10	6	2	8	4	8	4	2	1	13	10	1	5	3	7	6
	Size	Y	13	8	11	5	10	17	16	9	7	6	5	21	8	13	11	12	5	15
		R	5	7	4	1	7	8	4	7	5	5	2	9	5	7	4	4	5	7
		G	8	4	4	1	6	9	5	5	6	4	2	10	9	3	4	1	11	4
		W	5	2	9	5	7	4	7	6	3	2	2	12	9	2	5	3	7	6
½ diameter of light	Br.	Y	10	16	6	6	4	22	4	22	6	5	3	24	13	11	8	4	2	26
		R	6	8	2	2	0	14	7	9	0	0	0	16	5	4	7	1	1	14
		G	4	9	3	1	2	13	5	9	2	0	0	16	2	10	4	0	4	12
		W	4	8	4	4	3	9	3	5	8	3	2	11	2	8	6	3	2	11
	Size	Y	14	12	6	8	8	16	7	18	7	7	5	20	16	7	9	8	6	18
		R	7	6	3	2	1	13	6	9	1	0	0	16	5	5	6	1	4	11
		G	4	7	5	2	9	5	3	9	4	1	3	12	5	8	3	1	7	8
		W	5	7	4	4	4	8	4	2	10	2	5	9	3	11	2	4	4	8
= diameter of light	Br.	Y	11	13	8	2	6	24	8	16	8	5	0	27	12	14	6	4	5	23
		R	4	5	7	2	0	14	0	14	2	0	0	16	2	8	6	0	1	15
		G	5	7	4	0	0	16	5	10	1	0	0	16	6	6	4	1	3	12
		W	6	7	3	1	1	14	5	11	0	0	1	15	4	3	9	3	3	10
	Size	Y	11	11	10	6	9	17	8	12	12	9	3	20	10	13	9	8	7	17
		R	3	8	5	4	3	9	0	11	5	0	2	14	3	8	5	2	1	13
		G	5	6	5	1	0	15	5	10	1	0	3	13	5	1	10	1	3	12
		W	5	6	5	0	8	8	4	12	0	1	0	15	4	3	9	3	3	10
2 × diameter of light	Br.	Y	9	17	6	6	9	17	6	11	15	1	7	24	9	4	19	8	5	19
		R	2	10	4	0	2	14	6	8	2	0	0	16	2	12	2	0	1	15
		G	4	7	5	1	4	11	2	12	2	2	1	13	6	7	3	3	3	10
		W	10	4	2	2	5	9	5	8	3	3	2	11	5	3	8	4	7	5
	Size	Y	5	20	7	6	9	17	7	12	13	4	7	21	15	7	10	8	8	16
		R	6	6	4	6	1	9	5	10	1	0	2	14	3	10	3	3	3	10
		G	2	10	4	0	3	13	5	9	2	5	2	9	4	9	3	3	4	9
		W	8	2	6	5	1	10	4	7	5	3	4	9	4	4	8	8	3	5
13 cm.	Br.	Y	8	7	17	13	8	11	12	14	6	4	13	15	9	13	10	7	10	15
		R	4	9	3	3	2	11	6	5	5	5	4	7	3	7	6	3	8	5
		G	5	5	6	5	6	6	4	4	8	0	3	13	5	10	1	5	8	3
		W	8	6	2	2	5	9	2	8	6	3	3	10	10	5	1	11	2	3
	Size	Y	7	11	14	13	8	11	10	11	11	9	17	6	13	14	5	8	9	15
		R	3	8	5	1	4	11	6	6	4	6	3	7	6	4	6	4	9	3
		G	5	5	6	6	7	3	6	7	3	1	6	9	1	11	4	7	5	4
		W	8	7	1	1	6	9	0	10	6	1	5	10	7	6	3	7	6	3

Third Apparatus, first series. *Results with all four colors together given for three apertures and five divergences.*

TABLE VIII—INDIVIDUAL RESULTS—SUBJECT F.

Distance between lights	Judgment on	1 cm. Horiz Lf = Rt	1 cm. Vert Up = Lw	2 cm. Horiz Lf = Rt	2 cm. Vert Up = Lw	4 cm. Horiz Lf = Rt	4 cm. Vert Up = Lw	Total on 1, 2 and 4 cm. lights Horiz Lf = Rt	Total on 1, 2 and 4 cm. lights Vert Up = Lw
0 cm.	Br.	2 13 5 65%=	3 5 12 60%Lw	8 9 3 45%=	3 4 13 65%Lw	12 6 2 30%=	2 8 10 50%Lw	22 28 10 47%=	8 17 35 58%Lw
	Size	4 8 8 40%=	4 6 10 50%Lw	7 5 8 25%=	4 4 12 60%Lw	9 3 8 15%=	4 11 5 25%Lw	20 16 24 27%=	12 21 27 45%Lw
½ diameter of light	Br.	5 13 2 65%=	4 0 16 80%Lw	1 16 3 80%=	2 0 18 90%Lw	3 13 4 65%=	3 0 17 85%Lw	9 42 9 70%=	9 0 51 85%Lw
	Size	6 11 3 55%=	5 5 10 50%Lw	3 14 3 70%=	2 5 13 65%Lw	7 8 5 40%=	4 6 10 50%Lw	16 33 11 55%=	11 16 33 55%Lw
= diameter of light	Br.	4 10 6 50%=	1 2 17 85%Lw	2 18 0 90%=	0 0 20 100%Lw	2 13 5 65%=	0 4 16 80%Lw	8 41 11 68%=	1 6 53 88%Lw
	Size	5 9 6 45%=	4 6 10 50%Lw	2 17 1 85%=	0 5 15 75%Lw	3 9 8 45%=	2 6 12 60%Lw	10 35 15 58%=	6 17 37 62%Lw
2 × diameter of light	Br.	2 16 2 80%=	0 8 12 60%Lw	0 14 6 70%=	0 4 16 80%Lw	3 8 9 40%=	5 4 11 55%Lw	5 38 17 63%=	5 16 39 65%Lw
	Size	1 14 5 70%=	6 5 9 45%Lw	3 14 3 70%=	4 5 11 55%Lw	6 12 2 60%=	10 4 6 30%Lw	10 40 10 67%=	20 14 26 43%Lw
13 cm.	Br.	7 4 9 20%=	3 4 13 65%Lw	4 9 7 45%=	0 4 16 80%Lw	8 6 6 30%=	7 7 6 30%Lw	19 19 22 32%=	10 15 35 58%Lw
	Size	5 8 7 40%=	1 11 8 40%Lw	2 10 8 50%=	4 10 6 30%Lw	7 7 6 35%=	3 9 8 40%Lw	14 25 21 42%=	8 30 22 37%Lw
Total	Br.	20 56 24 56%=	11 19 70 70%Lw	15 66 19 66%=	5 12 83 83%Lw	28 46 26 47%=	17 23 60 60%Lw	63 168 69 56%=	33 54 213 71%Lw
	Size	21 50 29 50%=	20 33 47 47%Lw	17 60 23 60%=	14 29 57 57%Lw	32 39 29 39%=	23 36 41 41%Lw	70 149 81 50%=	57 98 145 48%Lw
Total without 13 cm. position	Br.	13 52 15 65%=	8 15 57 71%Lw	11 57 12 71%=	5 8 67 84%Lw	20 40 20 50%=	10 16 54 68%Lw	44 149 47 62%=	23 39 178 74%Lw
	Size	16 42 22 53%=	19 22 39 49%Lw	15 50 15 63%=	10 19 51 64%Lw	25 32 23 40%=	20 27 33 41%Lw	56 124 60 52%=	49 68 123 51%Lw

Discussion of Table VIII

In the above table the characteristic phenomenon appears as follows:

A—Comparison of the three sizes of apertures. It appears most clearly, in both size and brightness judgments, with the medium size (2 cm.) and is least noticeable with the 4 cm. aperture. This is true both for the totals including the 13 cm. divergence results and for the totals without these results but it is somewhat more apparent in the latter case.

B—Comparison of the five divergences. It appears most clearly, both in size and brightness judgments, where the divergence was either ½ the diameter of one light or was equal to the diameter. It was least evident in the extremes, *i.e.* where the divergence was 13 cm. and where it was 0. The judgments where the divergence was twice the light diameter showed the phenomenon considerably less clearly than where it was equal to or ½ the light diameter but they were more nearly in a class with these than with those judgments where the divergence was at either of the extremes.

C—Comparison of size with brightness judgments. The phenomenon appeared more clearly in the latter throughout. In the fifteen separate sets given above (three apertures, each in five different divergences) the phenomenon failed to appear once in brightness judgments (4 cm.-13 cm.), twice in size judgments (4 cm.-0 cm., 2 cm.-13 cm.). It appeared very slightly in three sets of size judgments (1 cm.-0 cm., 1 cm.-2 x., 4 cm-13 cm.) and the reverse case, *i.e.* preference for the upper light, appeared in one set (4 cm.-2 x.). In two sets of brightness judgments the preference for the lower light was paralleled by an equal or greater preference for one of the lights in the horizontal judgments (4 cm.-0 cm., 4 cm.- 2 x.). In these fifteen sets the phenomenon appeared more clearly in the size judgments than in the brightness judgments but once (4 cm.-13 cm.), was about equally noticeable in the two types of judgment three times (2 cm.-2 x., 4 cm.-0 cm., 2 cm.-0 cm.), and was more apparent in the brightness judgments eleven times.

TABLE IX—INDIVIDUAL RESULTS—SUBJECT H.

Distance between lights	Judgment on	Diameter of lights: 1 cm. Horiz Lf = Rt	1 cm. Vert Up = Lw	2 cm. Horiz Lf = Rt	2 cm. Vert Up = Lw	4 cm. Horiz Lf = Rt	4 cm. Vert Up = Lw	Total on 1, 2 and 4 cm. lights Horiz Lf = Rt	Total on 1, 2 and 4 cm. lights Vert Up = Lw
0 cm.	Size Br.	6 8 6 40%=	3 4 13 65%Lw	3 13 4 65%=	2 3 15 75%Lw	2 12 6 60%=	5 5 10 50%Lw	11 33 16 55%=	10 12 38 63%Lw
	Size Br.	8 8 4 40%=	2 7 11 55%Lw	6 9 5 45%=	3 5 12 60%Lw	7 8 5 40%=	5 8 7 35%Lw	21 25 14 42%=	10 20 30 50%Lw
½ diameter of light	Size Br.	5 13 2 65%=	0 4 16 80%Lw	2 17 1 85%=	0 3 17 85%Lw	5 10 5 50%=	2 3 15 75%Lw	12 40 8 67%=	2 10 48 80%Lw
	Size Br.	6 11 3 55%=	2 9 9 45%Lw	4 14 2 70%=	1 4 15 75%Lw	8 8 4 40%=	4 4 12 60%Lw	18 33 9 55%=	7 17 36 60%Lw
= diameter of light	Size Br.	4 14 2 70%=	0 2 18 90%Lw	2 18 0 90%=	0 0 20 100%Lw	3 12 5 60%=	0 4 16 80%Lw	9 44 7 73%=	0 6 54 90%Lw
	Size Br.	3 13 4 65%=	0 6 14 70%Lw	4 14 2 70%=	2 0 18 90%Lw	2 8 10 40%=	2 4 14 70%Lw	9 35 16 58%=	4 10 46 77%Lw
2 × diameter of light	Size Br.	3 13 4 65%=	2 7 11 55%Lw	2 16 2 80%=	0 5 15 75%Lw	5 6 9 30%=	3 8 9 45%Lw	10 35 15 58%=	5 20 35 58%Lw
	Size Br.	4 11 5 55%=	4 5 11 55%Lw	1 15 4 75%=	2 5 13 65%Lw	5 7 8 35%=	4 9 7 35%Lw	10 33 17 55%=	10 19 31 52%Lw
13 cm.	Size Br.	7 3 10 15%=	5 6 9 45%Lw	9 3 8 15%=	5 6 9 45%Lw	9 6 5 30%=	7 5 8 40%Lw	25 12 23 20%=	17 17 26 43%Lw
	Size Br.	8 4 8 20%=	6 5 9 45%Lw	7 5 8 25%=	4 6 10 50%Lw	8 8 4 40%=	8 7 5 25%Lw	23 17 20 28%=	18 18 24 40%Lw
Total	Size Br.	25 51 24 51%=	10 23 67 67%Lw	18 67 15 67%=	7 17 76 76%Lw	24 46 30 46%=	17 25 58 58%Lw	67 164 69 55%=	34 65 201 67%Lw
	Size Br.	29 47 24 47%=	14 32 54 54%Lw	22 57 21 57%=	12 20 68 68%Lw	30 39 31 39%=	23 32 45 45%Lw	81 143 76 48%=	49 84 167 56%Lw
Total without 13 cm. position	Size Br.	18 48 14 60%=	5 17 58 73%Lw	9 64 7 80%=	2 11 67 84%Lw	15 40 25 50%=	10 20 50 63%Lw	42 152 46 63%=	17 48 175 73%Lw
	Size Br.	21 43 16 54%=	8 27 45 56%Lw	15 52 13 64%=	8 14 58 73%Lw	22 31 27 39%=	15 25 40 50%Lw	58 126 56 53%=	31 66 143 60%Lw

Discussion of Table IX

In the above table the characteristic phenomenon appears as follows:

A—Comparison of the three sizes of apertures. It appears most clearly, both in size and brightness judgments, with the medium size (2 cm.) and is least noticeable in the 1 cm. aperture. This is true both for the totals including the 13 cm. divergence results and for the totals without these results but it is decidedly more apparent in the latter case.

B—Comparison of the five divergences. The phenomenon appears most clearly, both in size and brightness, where the divergence was equal to the diameter of one light and decreasingly in the other divergences in the following order: ½ the light diameter, 2 x. the light diameter, 0 divergence, 13 cm.

C—Comparison of size with brightness judgments. The phenomenon appeared more clearly in the latter throughout. In the fifteen sets given above (three apertures, each in five different divergences), the phenomenon appeared in every set of brightness judgments, failed to appear in one set of size judgments (4 cm.-13 cm.). It appeared only slightly in one set of size judgments (4 cm.-0 cm.) and in one set of brightness judgments (4 cm.-13 cm.). The reverse case, i.e. preference for the upper light, appeared in one set of size judgments (4 cm-13 cm.). In one set of brightness judgments (4 cm.-13 cm.) and in one set of size judgments (4 cm.-0 cm.) the preference for the lower light was paralleled by an equal or greater preference for one of the lights in the horizontal position. In these fifteen sets the phenomenon appeared more clearly in the size judgments than in the brightness judgments but once (2 cm.-13 cm.), was about equally noticeable in the two types of judgment twice (1 cm.-0 cm., 1 cm.-13 cm.), and was more apparent in the brightness judgments twelve times.

TABLE X—Individual Results—Subject A.

Distance between lights	Judgment on	Diameter of lights: 1 cm. Horiz Lf = Rt	1 cm. Vert Up = Lw	2 cm. Horiz Lf = Rt	2 cm. Vert Up = Lw	4 cm. Horiz Lf = Rt	4 cm. Vert Up = Lw	Total on 1, 2 and 4 cm. lights Horiz Lf = Rt	Total Vert Up = Lw
0 cm.	Br.	7 4 9 20%=	5 4 11 55%Lw	10 3 7 15%=	6 0 14 70%Lw	10 5 5 25%=	4 4 12 60%Lw	27 12 21 20%=	15 8 37 62%Lw
	Size	9 4 7 20%=	4 6 10 50%Lw	11 3 6 15%=	5 1 14 70%Lw	8 7 5 35%=	5 4 11 55%Lw	28 14 18 23%=	14 11 35 58%Lw
½ diameter of light	Br.	9 3 8 15%=	5 0 15 75%Lw	10 2 8 10%=	2 0 18 90%Lw	7 5 8 25%=	1 0 19 95%Lw	26 10 24 17%=	8 0 52 87%Lw
	Size	10 3 7 15%=	4 0 16 80%Lw	8 4 8 20%=	3 1 16 80%Lw	7 8 5 40%=	4 2 14 70%Lw	25 15 20 25%=	11 3 46 77%Lw
= diameter of light	Br.	10 2 8 10%=	0 0 20 100%Lw	9 2 9 10%=	1 0 19 95%Lw	11 0 9 0%=	4 0 16 80%Lw	30 4 26 7%=	5 0 55 92%Lw
	Size	9 1 10 5%=	3 3 14 70%Lw	4 7 9 35%=	2 1 17 85%Lw	8 2 10 10%=	6 0 14 60%Lw	21 10 29 17%=	11 4 45 75%Lw
2 × diameter of light	Br.	12 3 5 15%=	2 0 18 90%Lw	8 5 7 25%=	3 1 16 80%Lw	5 6 9 30%=	5 1 14 70%Lw	25 14 21 23%=	10 2 48 80%Lw
	Size	7 7 6 35%=	3 0 17 85%Lw	8 5 7 25%=	4 1 15 75%Lw	7 7 6 35%=	2 3 15 75%Lw	22 19 19 32%=	9 4 47 78%Lw
13 cm.	Br.	4 9 7 45%=	7 7 6 30%Lw	6 9 5 45%=	3 7 10 50%Lw	7 10 3 50%=	5 8 7 35%Lw	17 28 15 47%=	15 22 23 38%Lw
	Size	6 7 7 35%=	6 7 7 35%Lw	7 8 5 40%=	5 7 8 40%Lw	8 8 4 40%=	7 6 7 35%Lw	21 23 16 38%=	18 20 22 37%Lw
Total	Br.	42 21 37 21%=	19 11 70 70%Lw	43 21 36 21%=	15 8 77 77%Lw	40 26 34 26%=	19 13 68 68%Lw	125 68 107 23%=	53 32 215 72%Lw
	Size	41 22 37 22%=	20 16 64 64%Lw	38 27 35 27%=	19 11 70 70%Lw	38 32 30 32%=	24 15 61 61%Lw	117 81 102 27%=	63 42 195 65%Lw
Total without 13 cm. position	Br.	38 12 30 15%=	12 4 64 80%Lw	37 12 31 15%=	12 1 67 84%Lw	33 16 31 20%=	14 5 61 76%Lw	108 40 92 17%=	38 10 192 80%Lw
	Size	35 15 30 19%=	14 9 57 71%Lw	31 19 30 24%=	14 4 62 78%Lw	30 24 26 30%=	17 9 54 68%Lw	96 58 86 24%=	45 22 173 72%Lw

Discussion of Table X

In the above table the characteristic phenomenon appears as follows:

A—Comparison of the three sizes of aperture. It appears most clearly, both in size and brightness judgments, with the medium size (2 cm.) and is least noticeable with the 4 cm. aperture. This is, in a measure, true both for the totals including the 13 cm. divergence results and for the totals without these results but the difference between the three apertures is less noticeable in the totals without the 13 cm. divergence results than in those which contain these results.

B—Comparison of the five divergences. It appears most clearly, both in size and brightness judgments, where the divergence was either ½ the diameter of one light or was equal to the diameter. It was decreasingly present in the other divergences in the following order; divergence 2 x. the light diameter, o divergence, 13 cm. divergence.

C—Comparison of size with brightness judgments. The phenomenon was, on the whole, more striking in the brightness judgments than in the size judgments. This did not, however, hold for the O and 2 x. divergences, where it was about equally noticeable. In the fifteen sets given above the phenomenon failed to appear once in brightness judgments (1 cm.-13 cm.), once in size judgments (4 cm.-13 cm.). It appeared only slightly in one set of brightness judgments (4 cm.-13 cm.) and in one set of size judgments (1 cm.-13 cm.). In one set of brightness judgments (4 cm.-13 cm.) and in one set of size judgments (1 cm.-13 cm.) the preference for the lower light was paralleled by an equal or greater preference for one of the lights in the horizontal position. In these fifteen sets of judgments the phenomenon appeared more clearly in size judgments than in brightness judgments three times (1 cm-½, 4 cm.-2 x., 1 cm.-13 cm.), was about equally noticeable in the two types of judgments twice (1 cm.-o cm., 2 cm.-o cm.) and was more apparent in the brightness judgments ten times.

TABLE XI—INDIVIDUAL RESULTS—SUBJECT P.

Distance between lights	Judgment on	1 cm. Horiz Lf = Rt	1 cm. Vert Up = Lw	2 cm. Horiz Lf = Rt	2 cm. Vert Up = Lw	4 cm. Horiz Lf = Rt	4 cm. Vert Up = Lw	Total on 1, 2 and 4 cm. lights Horiz Lf = Rt	Total on 1, 2 and 4 cm. lights Vert Up = Lw
0 cm.	Br.	10 1 9 5%=	1 7 12 60%Lw	9 8 3 40%=	7 1 12 60%Lw	6 11 3 55%=	5 5 10 50%Lw	25 20 15 33%=	13 13 34 57%Lw
	Size	10 1 9 5%=	2 11 7 35%Lw	8 10 2 50%=	5 1 14 70%Lw	7 7 6 35%=	6 5 9 45%Lw	25 18 17 30%=	13 17 30 50%Lw
½ diameter of light	Br.	5 12 3 60%=	4 5 4 20%Lw	6 10 4 50%=	4 2 14 70%Lw	7 5 8 25%=	2 6 12 60%Lw	18 27 15 45%=	10 13 37 62%Lw
	Size	8 7 5 35%=	5 8 7 35%Lw	5 6 9 30%=	4 3 13 65%Lw	7 7 6 35%=	2 9 9 45%Lw	20 20 20 33%=	11 20 29 48%Lw
= diameter of light	Br.	8 6 6 30%=	4 3 13 65%Lw	5 13 2 65%=	4 1 15 75%Lw	8 6 6 30%=	4 4 12 60%Lw	21 25 14 42%=	12 8 40 67%Lw
	Size	7 8 5 40%=	4 5 11 55%Lw	7 7 6 35%=	6 2 12 60%Lw	9 6 5 30%=	4 4 12 60%Lw	23 21 16 35%=	14 11 35 58%Lw
2 × diameter of light	Br.	8 6 6 30%=	5 5 10 50%Lw	9 4 7 20%=	3 0 17 85%Lw	9 6 5 30%=	2 3 15 75%Lw	26 16 18 27%=	10 8 42 70%Lw
	Size	9 6 5 30%=	4 4 12 60%Lw	9 4 7 20%=	2 4 14 70%Lw	8 4 8 20%=	6 2 12 60%Lw	26 14 20 23%=	12 10 38 47%Lw
13 cm.	Br.	7 11 2 55%=	7 4 9 45%Lw	5 10 5 55%=	4 6 10 50%Lw	3 13 4 65%=	7 8 5 25%Lw	15 34 11 57%=	18 18 24 40%Lw
	Size	4 12 4 60%=	8 2 10 50%Lw	6 11 3 55%=	4 8 8 40%Lw	4 12 4 60%=	8 7 5 25%Lw	14 35 11 58%=	20 17 23 38%Lw
Total	Br.	38 36 26 36%=	21 24 55 55%Lw	34 45 21 45%=	22 10 68 68%Lw	33 41 26 41%=	20 26 54 54%Lw	105 122 73 41%=	63 60 177 59%Lw
	Size	38 34 28 34%=	23 30 47 47%Lw	35 38 27 38%=	21 18 61 61%Lw	35 36 29 36%=	26 27 47 47%Lw	108 108 84 36%=	70 75 155 52%Lw
Total without 13 cm. position	Br.	31 25 24 31%=	14 20 46 58%Lw	29 35 16 44%=	18 4 58 73%Lw	30 28 22 35%=	13 18 49 61%Lw	90 88 62 37%=	45 42 153 64%Lw
	Size	34 22 24 28%=	15 28 37 46%Lw	29 27 24 34%=	17 10 53 66%Lw	31 24 25 30%=	18 20 42 53%Lw	94 73 73 30%=	50 58 132 55%Lw

Discussion of Table XI

In the above table the characteristic phenomenon appears as follows:

A—Comparison of the three sizes of apertures. It appears most clearly, both in size and brightness judgments, in the medium size (2 cm.). This is true both for the totals including the 13 cm. divergence results and for the totals without these results. In the totals including the 13 cm. divergence results it appears about equally with the 1 cm. and 4 cm. apertures. In the totals without the 13 cm. divergence results it appears more clearly in the 4 cm. aperture than with the 1 cm. In both totals, however, the 1 cm. and 4 cm. aperture results show the phenomenon to an appproximately equal extent while the 2 cm. aperture results show it much more clearly than either of the other sizes.

B—Comparison of the five divergences. It appears most clearly, both in size and brightness, where the divergence was 2 x. the light diameter. It was decreasingly present in the other divergences in the following order; divergence ½ light diameter, equal to light diameter, 0 divergence, 13 cm. divergence.

C—Comparison of size with brightness judgments. The phenomenon appeared more clearly in the latter throughout. In the fifteen sets given above it failed to appear twice in brightness judgments (1 cm.-½, 4 cm.-13 cm.), once in size judgments (4 cm.-13 cm.). It appeared very slightly in one set of brightness judgments (1 cm.-13 cm), twice in size judgments (1 cm.-½, 1 cm.-13 cm.). The reverse case, *i.e.* preference for the upper light, appeared once in brightness (4 cm.-13 cm.), once in size (4 cm.-13 cm.) judgments. In two sets of brightness judgments (1 cm.-13 cm., 2 cm.-0 cm.) and two sets of size judgments (2 cm.-0 cm., 1 cm.-½) the preference for the lower light was paralleled by an equal or greater preference for one of the lights in the horizontal position. In these fifteen sets the phenomenon appeared more clearly in the size than in the brightness judgments three times (2 cm.-0 cm., 1 cm.-½, 1 cm.-2 x.), was about equally noticeable in the two types of judgment twice (4 cm.-equal, 1 cm.-13 cm.) and was more noticeable in the brightness judgments ten times.

Discussion of Tables VIII-XI

A—Comparison of the three sizes of apertures. It was distinctly more evident in the medium (2 cm.) size than in either of the other apertures. This was true for all subjects and for totals both with and without the 13 cm. divergence results. The relative importance of the phenomenon in the 1 cm. and 4 cm. apertures varied with the different subjects. For two subjects (F. and A.) it was least noticeable in the 4 cm. aperture. For one subject (H.) the opposite was true, while for the fourth subject (P.) the 1 cm. aperture showed the phenomenon least clearly in the totals without the 13 cm. divergence results but the two apertures were about equal in this respect in the totals including the 13 cm. divergence results. For 3 subjects (F., H. and P.) the difference between the three apertures, as to the importance of the phenomenon, appeared more clearly in the totals without the 13 cm. divergence results but for one subject (A.) the reverse was the case.

B—Comparison of the five divergences. Taking the average of all subjects the phenomenon appeared most clearly in the judgments where the divergence was equal the diameter of one light. It was decreasingly important in the other divergences in the following order; divergence ½ light diameter, divergence 2 x. light diameter, 0 divergence, 13 cm. divergence. This order did not hold exactly for each individual subject (see individual tables 8 to 11). The greatest variation from the average occurred with subject P., where the phenomenon was most apparent with the divergence 2 x the light diameter, and decreasingly present with the divergence ½ the light diameter, equal to the diameter, 0 divergence and 13 cm. divergence. With all subjects the 13 cm. divergence showed the phenomenon least clearly and the 0 divergence was next to the lowest in this respect.

In no case, with any subject, did the phenomenon wholly fail to appear, nor did the reverse case appear, in the totals for any one divergence (all three apertures), or in the totals for any one aperture (all five divergences). This holds true both for size and brightness judgments.

It appeared only slightly in several of the 13 cm. divergence totals, particularly those of the size judgments.

C—Comparison of horizontal with vertical judgments. The judgments of H. and F. ran very closely together throughout. This is particularly striking in the grand totals but is quite evident in the totals for particular apertures and divergences. Both averaged over 50 per cent of equality judgments in the horizontal position and over 60 per cent of judgments favoring the lower light in the vertical position, both in size and brightness. The judgments of equality in the vertical position averaged, with these two subjects, under 30 per cent and for the totals without 13 cm. results, under 20 per cent for both size and brightness. Both showed a slight preference for the right hand light in the horizontal position. This was by no means constant and was so slight as to be readily noticed only in the grand totals. It averaged less than 1 per cent. Subject P. showed the characteristic preference for the lower light less strikingly than the two preceding subjects. His judgments for this light averaged between 50 per cent and 60 per cent with a larger number of judgments for the upper light than was the case with the two previous subjects. His judgments in the horizontal position rather consistently favored the left hand light and his judgments of equality were less numerous in this position than was the case in the judgments of H. and F. His preference for the left hand light, however, never equaled the preference for the lower light in the totals of any aperture or divergence and in the grand totals this prference for the left was much less than the preference for the lower. In only one case (size totals, without 13 cm. divergence, for the 1 cm. aperture) were the equality judgments of this subject greater in the vertical than in the horizontal position and in the grand totals the horizontal equality judgments were much in excess of the vertical. The vertical judgments of subject A. followed those of subjects H. and F. rather closely. His judgments favoring the lower light were even more numerous than those of subjects H. and F. This was partially compensated by the fact that his judgments favoring the upper light were also

more numerous than those of H. and F. and the phenomenon was, consequently, slightly less noticeable in his case than in that of H. and F., though decidedly more so than in the case of subject P. His results differed from those of the three other subjects in showing a much smaller number of judgments of equality in both the vertical and horizontal positions. These equality judgments were, however, consistently more numerous in the horizontal than in the vertical position and the preference shown for the left hand light in the horizontal judgments equalled that shown for the lower light in only one case (size totals for 13 cm. divergence) and in the grand totals was very much less, in both size and brightness.

Third Apparatus, first series. Results with all three apertures taken together given for four colors and five divergences

TABLE XII—INDIVIDUAL RESULTS—SUBJECT F.

Distance between lights Judgment on	Color: Y Horiz Lf = Rt	Y Vert Up = Lw	R Horiz Lf = Rt	R Vert Up = Lw	G Horiz Lf = Rt	G Vert Up = Lw	W Horiz Lf = Rt	W Vert Up = Lw	Total Horiz Lf = Rt	Total Vert Up = Lw
0 cm. Size	10 12 2 50%=	2 10 12 50%Lw	2 8 2 67%=	1 2 9 75%Lw	6 4 2 33%=	3 2 7 58%Lw	4 4 4 33%=	2 3 7 58%Lw	22 28 10 47%=	8 17 35 58%Lw
Br.	9 5 10 21%=	6 8 10 42%Lw	3 5 4 42%=	2 5 5 42%Lw	4 4 4 33%=	3 4 5 83%Lw	4 2 6 17%=	1 4 7 58=Lw	20 16 24 27%=	12 21 27 45%Lw
½ diameter of light Size	3 18 3 75%=	4 0 20 83%Lw	4 7 1 58%=	2 0 10 83%Lw	1 9 2 75%=	1 0 11 92%Lw	1 8 3 67%=	2 0 10 83%Lw	9 42 9 70%=	9 0 51 85%Lw
Br.	8 12 4 50%=	6 6 12 50%Lw	3 6 3 50%=	2 2 8 67%Lw	2 8 2 67%=	1 4 7 58%Lw	3 7 2 58%=	2 4 6 50%Lw	16 33 11 55%=	11 16 33 55%Lw
= diameter of light Size	4 14 6 58%=	0 3 21 88%Lw	1 8 3 67%=	0 1 11 92%Lw	1 11 0 92%=	0 1 11 92%Lw	2 8 2 67%=	1 1 10 83%Lw	8 41 11 68%=	1 6 53 88%Lw
Br.	4 13 7 54%=	2 8 14 58%Lw	2 9 1 75%=	4 3 5 42%Lw	2 6 4 50%=	0 2 10 83%Lw	2 7 3 58%=	0 4 8 67%Lw	10 35 15 58%=	6 17 37 62%Lw
2 × diameter of light Size	0 12 12 50%=	4 5 15 63%Lw	0 9 3 75%=	0 2 10 83%Lw	2 8 1 67%=	0 5 7 58%Lw	3 8 1 67%=	1 4 7 58%Lw	5 38 17 63%=	5 16 39 65%Lw
Br.	5 15 4 63%=	8 6 10 42%Lw	2 9 1 75%=	3 3 6 50%Lw	1 10 1 83%=	4 4 4 33%Lw	2 6 4 50%=	5 1 6 50%Lw	10 40 10 67%=	20 14 26 43%Lw
13 cm. Size	8 6 10 25%=	2 7 15 63%Lw	3 8 1 67%=	2 3 7 58%Lw	3 2 7 17%=	2 3 7 58%Lw	5 3 4 25%=	4 2 6 50%Lw	19 19 22 32%=	10 15 35 58%Lw
Br.	6 10 8 42%=	4 12 8 33%Lw	3 5 4 42%=	1 5 6 50%Lw	2 6 4 50%=	2 6 4 33%Lw	3 4 5 33%=	1 7 4 33%Lw	14 25 21 42%=	8 30 22 37%Lw
Total Size	25 62 33 53%=	12 25 83 69%Lw	10 40 10 67%=	5 8 47 78%Lw	13 35 12 58%=	6 11 43 72%Lw	15 31 14 52%=	10 10 40 67%Lw	63 168 69 56%=	33 54 213 71%Lw
Br.	32 55 33 46%=	26 40 54 45%Lw	13 34 13 57%=	12 18 30 50%Lw	11 34 15 57%=	10 20 30 50%Lw	14 26 20 43%=	9 20 31 52%Lw	70 149 81 50%=	57 98 145 48%Lw
Total without 13 cm. position Size	17 56 23 58%=	10 18 68 71%Lw	7 32 9 67%=	3 5 40 83%Lw	10 33 5 69%=	4 8 36 75%Lw	10 28 10 58%=	6 8 34 71%Lw	44 149 47 62%=	23 39 178 74%Lw
Br.	26 45 25 47%=	22 28 46 48%Lw	10 29 9 60%=	11 13 24 50%Lw	9 28 11 58%=	8 14 26 54%Lw	11 22 15 46%=	8 13 27 56%Lw	56 124 60 52%=	49 68 123 51%Lw

Discussion of Table XII

In the above table the characteristic phenomenon appears as follows:

A—Comparison of the four colors. In judgments on brightness it appears most clearly with the red, next with the green, next the yellow and least of all with the white. This holds true both of the totals including the 13 cm. divergence results and of those without these results. The difference is very slight, however, between the green and yellow in the totals with the 13 cm. results and between the yellow and white in the totals without the 13 cm. results. The most striking difference in the prominence of the phenomenon with the different colors in brightness judgments is concerned with the red, where it is distinctly more prominent than in any of the other colors, in both sets of totals. In judgments on size it appears most clearly with the white, next with the green, next the red and least of all with the yellow. This holds true both for the totals including the 13 cm. results and for the totals without these results but the difference between the white and green is very slight and the greater preference for the lower light in these colors is partially offset by a greater inequality in the horizontal judgments.

TABLE XIII—Individual Results—Subject H.

Distance between lights Judg-ment on	Color: Y Lf = Rt Horiz	Y Up = Lw Vert	R Lf = Rt Horiz	R Up = Lw Vert	G Lf = Rt Horiz	G Up = Lw Vert	W Lf = Rt Horiz	W Up = Lw Vert	Total Lf = Rt Horiz	Total Up = Lw Vert
0 cm. Size	6 14 4 58%=	8 2 14 58%Lw	2 8 2 66%=	1 3 8 66%Lw	2 8 2 66%=	0 4 8 66%Lw	1 3 8 25%=	1 3 8 66%Lw	11 33 16 55%=	10 12 38 63%Lw
Br.	7 12 5 50%=	4 4 16 66%Lw	4 4 4 33%=	4 2 6 50%Lw	7 3 2 25%=	0 8 4 33%Lw	3 6 3 50%=	2 6 4 33%Lw	21 25 14 42%=	10 20 30 50%Lw
½ diam-eter of light Size	6 15 3 63%=	0 3 21 88%Lw	2 10 0 83%=	0 1 11 92%Lw	2 8 2 66%=	0 2 10 83%Lw	2 7 3 58%=	2 4 6 50%Lw	12 40 8 67%=	2 10 48 80%Lw
Br.	10 10 4 42%=	6 2 16 66%Lw	3 9 0 75%=	0 1 11 92%Lw	2 7 3 58%=	1 9 2 17%Lw	3 7 2 58%=	0 5 7 58%Lw	18 33 9 55%=	7 17 36 60%Lw
= diam-eter of light Size	6 17 1 71%=	0 4 20 83%Lw	0 9 3 75%=	0 0 12 100%Lw	2 10 0 83%=	0 0 12 100%Lw	1 8 3 66%=	0 2 10 83%Lw	9 44 7 73%=	0 6 54 90%Lw
Br.	5 13 6 54%=	4 6 14 58%Lw	0 10 2 83%=	0 0 12 100%Lw	4 4 4 33%=	0 0 12 100%Lw	0 8 4 66%=	0 4 8 66%Lw	9 35 16 58%=	4 10 46 77%Lw
2 × diam-eter of light Size	6 8 10 33%=	2 12 10 42%Lw	0 11 1 92%=	0 1 11 92%Lw	1 9 2 75%=	2 1 9 75%Lw	3 7 2 58%=	1 6 5 42%Lw	10 35 15 58%=	5 20 35 58%Lw
Br.	3 11 10 46%=	3 14 7 29%Lw	4 7 1 58%=	3 1 8 66%Lw	0 11 1 92%=	1 2 9 75%Lw	3 4 5 33%=	3 2 7 58%=	10 33 17 55%=	10 19 31 52%Lw
13 cm. Size	8 5 11 21%=	7 8 9 38%Lw	2 5 5 42%=	3 2 7 58%Lw	7 1 4 8%=	2 4 6 50%Lw	8 1 3 8%=	5 3 4 33%Lw	25 12 23 20%=	17 17 26 43%Lw
Br.	10 6 8 25%=	8 7 9 38%Lw	4 4 4 33%=	3 4 5 42%Lw	4 3 5 25%=	4 4 4 33%Lw	5 4 3 33%=	3 3 6 50%Lw	23 17 20 28%=	18 18 24 40%Lw
Total Size	32 59 29 49%=	17 29 74 62%Lw	6 43 11 72%=	4 7 49 82%Lw	14 36 10 60%=	4 11 45 75%Lw	15 26 19 43%=	9 18 33 55%Lw	67 164 69 55%=	34 65 201 41%Lw
Br.	35 52 33 43%=	25 33 62 52%Lw	15 34 11 57%=	10 8 42 70%Lw	17 28 15 47%=	6 23 31 52%Lw	14 29 17 48%=	8 20 32 53%Lw	81 143 76 48%=	49 84 167 56%Lw
Total without 13 cm. position Size	24 54 18 56%=	10 21 65 68%Lw	4 38 6 79%=	1 5 42 88%Lw	7 35 6 73%=	2 7 39 81%Lw	7 25 16 52%=	4 15 29 60%Lw	42 152 46 63%=	17 48 175 73%Lw
Br.	25 46 25 48%=	17 26 53 55%Lw	11 30 7 63%=	7 4 37 77%Lw	13 25 10 52%=	2 19 27 56%Lw	9 25 14 52%=	5 17 26 54%Lw	58 126 56 53%=	31 66 143 60%Lw

Discussion of Table XIII

In the above table the characteristic phenomenon appears as follows:

A—Comparison of the four colors. In judgments on brightness it appears most clearly with the red, next with the green, next the yellow and least of all with the white. This holds true both of the totals including the 13 cm. divergence results and of the totals without these results, with the single exception that, in the totals without the 13 cm. results the yellow and white show the phenomenon to an approximately equal extent. In judgments on size it appears about equally with the red and green, in the totals including the 13 cm. results, while the green shows it most clearly in the totals without the 13 cm. results. In both sets of totals the yellow shows it least clearly and the white next to the least. In both size and brightness judgments for both sets of totals the red and green show it more consistently than the yellow and white, with the red slightly ahead. To this extent the prominence of the phenomenon in the four colors runs parallel in the size and brightness judgments but its relative prominence in the red and green does not run parallel in the two types of judgment, nor in the yellow and white.

TABLE XIV—INDIVIDUAL RESULTS—SUBJECT A.

Distance between lights	Judgment on	Color: Y Horiz Lf = Rt	Y Vert Up = Lw	R Horiz Lf = Rt	R Vert Up = Lw	G Horiz Lf = Rt	G Vert Up = Lw	W Horiz Lf = Rt	W Vert Up = Lw	Total Horiz Lf = Rt	Total Vert Up = Lw
0 cm.	Br.	13 3 8 13%=	8 0 16 66%Lw	2 6 4 50%=	2 2 8 66%Lw	4 3 5 25%=	0 4 8 66%Lw	8 0 4 0%=	5 2 5 42%Lw	27 12 21 20%=	15 8 37 62%Lw
	Size	13 5 6 21%=	8 2 14 58%Lw	3 6 3 50%=	2 3 7 58%Lw	5 3 4 25%=	0 3 9 75%Lw	7 0 5 0%=	4 3 5 42%Lw	28 14 18 23%=	14 11 35 58%Lw
½ diameter of light	Br.	11 5 8 21%=	5 0 19 79%Lw	8 0 4 0%=	0 0 12 100%Lw	5 3 4 25%=	0 0 12 100%Lw	2 2 8 17%=	3 0 9 75%Lw	26 10 24 17%=	8 0 52 87%Lw
	Size	10 7 7 29%=	5 2 17 71%Lw	7 2 3 17%=	0 0 12 100%Lw	5 2 5 17%=	1 1 10 83%Lw	3 4 5 33%=	5 0 7 58%Lw	25 15 20 25%=	11 3 46 77%Lw
= diameter of light	Br.	11 2 11 8%=	3 0 21 88%Lw	3 2 7 17%=	0 0 12 100%Lw	7 0 5 0%=	1 0 11 92%Lw	9 0 3 0%=	1 0 11 92%Lw	30 4 26 7%=	5 0 55 92%Lw
	Size	9 2 13 8%=	8 0 16 66%Lw	2 2 8 17%=	0 1 11 92%Lw	3 4 5 33%=	2 1 9 75%Lw	7 2 3 17%=	1 2 9 75%Lw	21 10 29 17%=	11 4 45 75%Lw
2 × diameter of light	Br.	10 4 10 17%=	4 2 18 75%Lw	4 6 2 50%=	0 0 12 100%Lw	4 4 4 33%=	1 0 11 92%Lw	7 0 5 0%=	5 0 7 58%Lw	25 14 21 23%=	10 2 48 80%Lw
	Size	9 7 8 29%=	3 2 19 79%Lw	4 6 2 50%=	1 0 11 92%Lw	3 5 4 42%=	1 1 10 83%Lw	6 1 5 8%=	4 1 7 58%Lw	22 19 19 32%=	9 4 47 78%Lw
13 cm.	Br.	8 8 8 33%=	7 6 11 46%Lw	3 6 3 50%=	5 5 2 17%Lw	2 8 2 66%=	1 9 2 17%Lw	4 6 2 50%=	2 2 8 66%Lw	17 28 15 47%=	15 22 23 38%Lw
	Size	10 6 8 25%=	9 6 9 38%Lw	3 5 4 42%=	5 4 3 25%Lw	3 6 3 50%=	3 7 2 17%Lw	5 6 1 50%=	1 3 8 66%Lw	21 23 16 38%=	18 20 22 37%Lw
Total	Br.	53 22 45 18%=	27 8 85 71%Lw	20 20 20 33%=	7 7 46 77%Lw	22 18 20 30%=	3 13 44 73%Lw	30 8 22 13%=	16 4 40 67%Lw	125 68 107 23%=	53 32 215 72%Lw
	Size	51 27 42 23%=	33 12 75 63%Lw	19 21 20 35%=	8 8 44 73%Lw	19 20 21 33%=	7 13 40 67%Lw	28 13 19 22%=	15 9 36 60%Lw	117 81 102 27%=	63 42 195 65%Lw
Total without 13 cm. position	Br.	45 14 37 15%=	20 2 74 77%Lw	17 14 17 29%=	2 2 44 92%Lw	20 10 18 21%=	2 4 42 88%Lw	26 2 20 4%=	14 2 32 67%Lw	108 40 92 16%=	38 10 192 80%Lw
	Size	41 21 34 22%=	24 6 66 69%Lw	16 16 16 33%=	3 4 41 85%Lw	16 14 18 29%=	4 6 38 79%Lw	23 7 18 15%=	14 6 28 58%Lw	96 58 86 24%=	45 22 173 72%Lw

Discussion of Table XIV

In the above table the characteristic phenomenon appears as follows:

A—Comparison of the four colors. In judgments on brightness it appears most clearly with the green, next with the red, next the yellow and least of all with the white. The one exception to this order is that the red and green, in totals without 13 cm. divergence results, are sensibly equal. In size judgments it appears, on the whole, most clearly with the red, next with the green, next the yellow and least of all with the white. The red and green, however, are sensibly equal in the totals with the 13 cm. results, as are also the yellow and white. The colors naturally fall into two pairs, the red and green running close together and the white and yellow. This is particularly the case in the size totals with 13 cm. results, as just mentioned under size results. In this characteristic of the pairing of the four colors the size and brightness results run parallel. Taken separately they do not run quite parallel as the green shows the phenomenon most clearly in the brightness totals with 13 cm. results while the red shows it most clearly in the size totals without 13 cm. results.

TABLE XV—Individual Results—Subject P.

Distance between lights	Judgment on	Color: Y Horiz Lf = Rt	Y Vert Up = Lw	R Horiz Lf = Rt	R Vert Up = Lw	G Horiz Lf = Rt	G Vert Up = Lw	W Horiz Lf = Rt	W Vert Up = Lw	Total Horiz Lf = Rt	Total Vert Up = Lw
0 cm.	Size	8 10 6 42%=	6 6 12 50%Lw	6 4 2 33%=	2 1 9 75%Lw	6 2 4 17%=	2 4 6 50%Lw	5 4 3 33%=	3 2 7 58%Lw	25 20 15 33%=	13 13 34 57%Lw
	Br.	8 8 8 33%=	5 6 13 54%Lw	4 6 2 50%=	2 4 6 50%Lw	6 2 4 17%=	3 4 5 42%Lw	7 2 3 17%=	3 3 6 50%Lw	25 18 17 30%=	13 17 30 50%Lw
½ diameter of light	Size	7 11 6 46%=	6 6 12 50%Lw	4 4 4 33%=	1 0 11 92%Lw	3 8 1 66%=	0 4 8 66%Lw	4 4 4 33%=	3 3 6 50%Lw	18 27 15 45%=	10 13 37 62%Lw
	Br.	9 8 7 33%=	6 9 9 38%Lw	5 3 4 25%=	1 2 9 75%Lw	3 7 2 58%=	1 5 6 50%Lw	3 2 7 17%=	3 4 5 42%Lw	20 20 20 33%=	11 20 29 48%Lw
= diameter of light	Size	10 10 4 42%=	8 4 12 50%Lw	2 8 2 66%=	2 0 10 83%Lw	6 2 4 17%=	0 2 10 83%Lw	3 5 4 42%=	2 2 8 66%Lw	21 25 14 42%=	12 8 40 67%Lw
	Br.	11 8 5 33%=	9 5 10 42%Lw	2 6 4 50%=	2 2 8 66%Lw	6 3 3 25%=	0 3 9 75%Lw	4 4 4 33%=	3 1 8 66%Lw	23 21 16 35%=	14 11 35 58%Lw
2 × diameter of light	Size	8 8 8 33%=	5 2 17 71%Lw	6 4 2 33%=	0 0 12 100%Lw	5 4 3 33%=	3 2 7 58%Lw	7 0 5 0%=	2 4 6 50%Lw	26 16 18 27%=	10 8 42 70%Lw
	Br.	10 6 8 25%=	4 2 18 75%Lw	4 4 4 33%=	2 2 8 66%Lw	7 2 3 17%=	2 2 8 66%Lw	5 2 5 17%=	4 4 4 33%Lw	26 14 20 23%=	12 10 38 63%Lw
13 cm.	Size	5 14 5 58%=	8 10 6 25%Lw	5 3 4 25%=	1 4 7 58%Lw	2 8 2 66%=	4 1 7 58%Lw	3 9 0 75%=	5 3 4 33%Lw	15 34 11 57%=	18 18 24 40%Lw
	Br.	4 14 6 58%=	9 9 6 25%Lw	5 4 3 33%=	2 3 7 58%Lw	3 8 1 66%=	5 1 6 50%Lw	2 9 1 75%=	4 4 4 33%Lw	14 35 11 58%=	20 17 23 38%Lw
Total	Size	38 53 29 44%=	33 28 59 49%Lw	23 23 14 38%=	6 5 49 82%Lw	22 24 14 40%=	9 13 38 63%Lw	22 22 16 37%=	15 14 31 52%Lw	105 122 73 41%Lw	63 60 177 59%Lw
	Br.	42 44 34 37%=	33 31 56 47%Lw	20 23 17 40%=	9 13 38 63%Lw	25 22 13 37%=	11 15 34 57%Lw	21 19 20 32%=	17 16 27 45%Lw	108 108 84 36%=	70 75 155 52%Lw
Total without 13 cm. position	Size	33 39 24 41%=	25 18 53 55%Lw	18 20 10 42%=	5 1 42 88%Lw	20 16 12 33%=	5 12 31 65%Lw	19 13 16 27%=	10 11 27 56%Lw	90 88 62 37%=	45 42 153 64%Lw
	Br.	38 30 28 31%=	24 22 50 52%Lw	15 19 14 40%=	7 10 31 65%Lw	22 14 12 29%=	6 14 28 58%Lw	19 10 19 21%=	13 12 23 48%Lw	94 73 73 30%=	50 58 132 55%Lw

Discussion of Table XV

In the above table the characteristic phenomenon appears as follows:

A—Comparison of the four colors. In judgments on brightness it appears most clearly with the red, next with the green, next the white and least of all with the yellow. This holds true both of the totals including the 13 cm. divergence results and of the totals without these results. In the size judgments the order is the same, with the single exception that the yellow and white have changed places, the white showing the effect least clearly in these judgments. The difference between the results for the yellow and white, in both brightness and size and for both sets of totals, is much less marked than the difference between the green and these two colors, or the difference between the red and green. In fact the phenomenon is almost equally prominent in the yellow and white.

Discussion of Tables XII-XV

A—Comparison of the four colors. *Considering the totals of all subjects together.* In judgments on brightness the phenomenon appears most clearly with the red, next with the green, next the yellow and least of all with the white. This holds true both for the totals including the 13 cm. divergence results and for those without these results. In judgments on size it appears most clearly with the red and green, these being sensibly equal in this respect, then with the white and least of all with the yellow. In both the size and brightness judgments the colors fall into pairs, with reference to the relative importance of the phenomenon. The red and green show a comparatively slight difference (in the size judgments they are practically equal) and they both show the phenomenon much more clearly than the yellow and white, which are, in turn, very much alike.

Considering the four subjects separately. In the judgments on brightness the order of importance of the phenomenon in the different colors is the same for two of the subjects, F. and H., as for the totals of all subjects. The order of the colors for subject

A. is altered by the appearance of the phenomenon most clearly in the green, with the red next. A similar shift occurs between the yellow and white with subject P., yellow showing the effect least clearly. An exception to the general tendency of the colors to group in pairs of red-green and white-yellow occurs with subject F. in that the green and yellow are very nearly equal in the totals with the 13 cm. results. In the judgments on size there is relatively little uniformity in the order of colors for the different subjects, arranged according to the prominence of the phenomenon. Only with subject H, in the totals including the 13 cm. results, does the order coincide with that for the totals of all subjects. With subject F. an almost complete reversal of the order in the size judgments takes place (W-G-R-Y). The order for subject A. is identical with the order of the totals for all subjects on brightness judgments but is not the same as his own order on brightness judgments. The order of subject P. is the same for size and brightness judgments and is very near the order of the totals for all subjects on size.

Third Apparatus, first series. Comparison of brightness and size judgments. Results, with all four colors together, given for three apertures and five divergences

The results are classified into four types of relationship between the judgments on size and those on brightness.

I. Those cases in which the lights were reported as equal in both brightness and size.

II. Those cases in which one light was reported as both brighter and larger.

III. Those cases in which one light was reported as brighter, the other as larger.

IV. Those cases in which the lights were reported as equal in one of the two factors but unequal in the other.

TABLE XVI—Individual Results—Subject F.

Distance between lights	Types of judgment	Diameter of lights— 1 cm. Horiz	1 cm. Vert	2 cm. Horiz	2 cm. Vert	4 cm. Horiz	4 cm. Vert	Total of 1, 2 and 4 cm. lights Horiz	Total of 1, 2 and 4 cm. lights Vert
0 cm.	I	8	3	5	3	3	8	16 27%	14 23%
	II	7	11	10	13	8	7	25 42%	31 52%
	III	0	1	1	2	6	2	7 11%	5 8%
	IV	5	5	4	2	3	3	12 20%	10 17%
½ diameter of light	I	5	4	5	6	7	6	17 28%	16 27%
	II	8	12	10	10	6	7	24 40%	29 48%
	III	3	0	2	3	4	0	9 15%	3 5%
	IV	4	4	3	1	3	7	10 17%	12 20%
= diameter of light	I	7	7	9	6	6	0	22 37%	13 22%
	II	7	8	5	10	8	7	20 33%	25 42%
	III	1	2	2	2	1	5	4 7%	9 15%
	IV	5	3	4	2	5	8	14 23%	13 22%
2 × diameter of light	I	3	1	5	5	6	4	14 23%	10 17%
	II	7	13	10	14	11	12	28 47%	39 65%
	III	3	2	2	0	0	2	5 8%	4 7%
	IV	7	4	3	1	3	2	13 22%	7 11%
13 cm.	I	2	4	5	11	3	2	10 17%	17 28%
	II	8	12	9	9	10	9	27 45%	30 50%
	III	3	2	3	0	0	4	6 10%	6 10%
	IV	7	2	3	0	7	5	17 28%	7 11%
Total	I	25	19	29	31	25	20	79 26%	70 23%
	II	37	56	44	56	43	42	124 42%	154 52%
	III	10	7	10	7	11	13	31 10%	27 9%
	IV	28	18	17	6	21	25	66 22%	49 16%
Total without 13 cm. position	I	23 29%	15 19%	24 30%	20 25%	22 28%	18 23%	69 29%	53 22%
	II	29 36%	44 55%	35 44%	47 59%	33 41%	33 41%	97 40%	124 52%
	III	7 9%	5 6%	7 9%	7 9%	11 14%	9 11%	25 10%	21 9%
	IV	21 26%	16 20%	14 18%	6 8%	14 18%	20 25%	49 20%	42 17%

TABLE XVII—INDIVIDUAL RESULTS—SUBJECT H.

Distance between lights	Types of judgment	Diameter of lights— 1 cm. Horiz		1 cm. Vert		2 cm. Horiz		2 cm. Vert		4 cm. Horiz		4 cm. Vert		Total of 1, 2 and 4 cm. lights Horiz		Total of 1, 2 and 4 cm. lights Vert	
0 cm.	I	7		3		9		3		6		5		22	37%	11	18%
	II	10		10		7		12		5		12		22	37%	34	57%
	III	1		2		0		3		1		0		2	3%	5	8%
	IV	2		5		4		2		8		3		14	23%	10	17%
½ diameter of light	I	11		4		14		2		8		2		33	55%	8	13%
	II	7		9		3		15		9		10		19	32%	34	57%
	III	0		2		0		0		1		5		1	2%	7	12%
	IV	2		5		3		3		2		3		7	12%	11	18%
= diameter of light	I	12		2		14		0		8		4		34	57%	6	10%
	II	4		14		2		17		7		14		13	22%	45	75%
	III	1		0		0		2		1		0		2	3%	2	3%
	IV	3		4		4		1		4		2		11	18%	7	12%
2 × diameter of light	I	10		5		14		5		4		6		28	47%	16	27%
	II	6		9		3		13		11		9		20	33%	31	52%
	III	0		4		0		2		0		0		0	0%	6	10%
	IV	4		2		3		0		5		5		12	20%	7	12%
13 cm.	I	3		5		3		6		5		5		11	18%	16	27%
	II	14		12		15		13		9		12		38	63%	37	62%
	III	2		2		0		1		2		0		4	7%	3	5%
	IV	1		1		2		0		4		3		7	12%	4	7%
Total	I	43		19		54		16		31		22		128	43%	57	19%
	II	41		54		30		70		41		57		112	37%	181	60%
	III	4		10		0		8		5		5		9	3%	23	8%
	IV	12		17		16		6		23		16		51	17%	39	13%
Total without 13 cm. position	I	40	50%	14	18%	51	64%	10	13%	26	33%	17	21%	117	49%	41	17%
	II	27	34%	42	53%	15	19%	57	71%	32	40%	45	56%	74	31%	144	60%
	III	2	3%	8	10%	0	0%	7	9%	3	4%	5	6%	5	2%	20	8%
	IV	11	14%	16	20%	14	18%	6	8%	19	24%	13	16%	44	18%	35	15%

Discussion of Table XVI

Comparison of size and brightness judgments.

In a large majority of cases the two types of judgment run together. (Approximately 70 per cent in the horizontal position and 75 per cent in the vertical.) The judgments of the second type alone make up nearly half of the total (47 per cent). The judgments of the third type, the extreme case of opposition between the brightness and size judgments, are correspondingly few in number (less than 10 per cent). The judgments of the fourth type make up about 19 per cent of the total. This type covers a large part of the cases in which a negative judgment was given, *i.e.* "cannot be sure of any difference," rather than a positive judgment, *i.e.* "they *are* equal." These negative judgments were much more frequent in the fourth type than in the first type. The judgments of the fourth type were somewhat more frequent in the horizontal than in the vertical position. In the fifteen sets given above (3 apertures, each in 5 divergences) it occurred more frequently in the horizontal position ten times, more frequently in the vertical twice and equally in the two positions three times. The judgments of the first type were decidedly more frequent in the horizontal and those of the second type in the vertical position. The judgments of the third type were practically equal in the two positions.

A—Comparison of the three sizes of apertures. The largest aperture, 4 cm., shows the smallest number of judgments tending to run together. With this aperture there are the smallest nomber of judgments of the first two types and the largest number of the third type. The medium sized aperture gives the largest number of identical size and brightness judgments (first and second types) with a number of opposite judgments (third type) approximately equal to those with the 1 cm. aperture. On the whole the size and brightness judgments tend to run most nearly together in the medium (2 cm.) aperture.

B—Comparison of the five divergences. There is very little difference between the five divergences in the extent to which the size and brightness judgments run parallel. This character-

istic is slightly more noticeable in the totals with divergence 2 x the light diameter than in those with the other divergences and slightly less noticeable with divergence = to the light diameter than in the other cases.

Discussion of Table XVII

Comparison of size and brightness judgments.

In a large majority of cases the two types of judgment run together. (Approximately 80 per cent both in the horizontal and vertical positions.) The judgments of the second type alone make up nearly half of the total (47 per cent), and in the vertical position these judgments amount to 60 per cent of the total judgments. The judgments of the third type are correspondingly few in number. (Approximately 5 per cent, and in the horizontal position less than 3 per cent.) The judgments of the fourth type make up about 16 per cent of the total. This type covers a large part of the cases in which a negative judgment was given. (See p. 74.) They were much more numerous in the fourth type than in the first type. The judgments of the fourth type were somewhat more numerous in the horizontal than in the vertical position. In only four of the fifteen sets given above were they more numerous in the vertical than in the horizontal position. The judgments of the first type were decidedly more numerous in the horizontal and those of the second type in the vertical position. The latter occurred nearly twice as frequently in the vertical as in the horizontal position. The judgments of the third type were about three times as numerous in the vertical as in the horizontal position.

A—Comparison of the three sizes of apertures. The medium sized aperture, 2 cm., shows the largest number of judgments tending to run together. With this aperture there are the largest number of judgments of the first two types and the smallest number of the third type. The smallest (1 cm.) and the largest (4 cm.) apertures are about equal in the tendency of the brightness and size judgments to coincide, with a slightly larger number of identical judgments (first and second types) in the 1 cm. aper-

ture, compensated for by a slightly larger number of opposite judgments (third type).

B—Comparison of the 5 divergences. The tendency of the size and brightness judgments to coincide in the different divergences is most noticeable in the divergence = to the light diameter, next in the 13 cm. divergence and decreasingly with the divergence twice the light diameter, ½ the diameter and 0 divergence. The difference between the five divergences in this respect is, however, not striking. Where it is most noticeable there are ninety-eight judgments of the first two types and four of the third type, as against eighty-nine of the first two types and seven of the third type where it is the least noticeable.

TABLE XVIII—INDIVIDUAL RESULTS—SUBJECT A.

Distance between lights	Types of judgment	Diameter of lights— 1 cm. Horiz	1 cm. Vert	2 cm. Horiz	2 cm. Vert	4 cm. Horiz	4 cm. Vert	Total of 1, 2 and 4 cm. lights Horiz	Total of 1, 2 and 4 cm. lights Vert
0 cm.	I	4	2	2	0	5	3	11 18%	5 8%
	II	12	12	14	18	11	14	37 62%	44 73%
	III	4	0	2	1	2	1	8 13%	2 3%
	IV	0	6	2	1	2	2	4 7%	9 15%
½ diameter of light	I	2	0	2	0	4	0	8 13%	0 0%
	II	15	19	16	18	11	15	42 70%	52 87%
	III	1	1	0	1	0	1	1 2%	3 5%
	IV	2	0	2	1	5	4	9 15%	5 8%
= diameter of light	I	1	0	1	0	0	0	2 3%	0 0%
	II	17	14	12	18	16	18	45 75%	50 83%
	III	1	3	0	1	2	2	3 5%	6 10%
	IV	1	3	7	1	2	0	10 17%	4 7%
2 × diameter of light	I	3	0	4	0	5	1	12 20%	1 2%
	II	12	17	14	17	11	16	37 62%	50 83%
	III	1	3	0	1	1	1	2 3%	5 8%
	IV	4	0	2	2	3	2	9 15%	4 7%
13 cm.	I	7	6	7	6	8	5	22 37%	17 28%
	II	10	12	10	10	10	11	30 50%	33 55%
	III	1	0	0	2	0	0	1 2%	2 3%
	IV	2	2	3	2	2	4	7 12%	8 13%
Total	I	17	8	16	6	22	9	55 18%	23 8%
	II	66	74	66	81	59	74	191 64%	229 76%
	III	8	7	2	6	5	5	15 5%	18 6%
	IV	9	11	16	7	14	12	39 13%	30 10%
Total without 13 cm. position	I	10 13%	2 3%	9 11%	0 0%	14 18%	4 5%	33 14%	6 3%
	II	56 70%	62 78%	56 70%	71 89%	49 61%	63 79%	161 67%	196 82%
	III	7 9%	7 9%	2 3%	4 5%	5 6%	5 6%	14 6%	16 7%
	IV	7 9%	9 11%	13 16%	5 6%	12 15%	8 10%	32 13%	22 9%

Discussion of Table XVIII

Comparison of size and brightness judgments.

In a very large majority of cases the brightness and size judgments coincide. (Approximately 80 per cent in the horizontal and 85 per cent in the vertical position.) The judgments of the second type alone make up nearly ¾ of the total (72 per cent). The judgments of the third type are correspondingly few in number (6 per cent of the vertical and horizontal judgments together). The judgments of the first and fourth types are approximately equal in number. The judgments of the fourth type are somewhat more numerous in the horizontal than in the vertical position. The negative judgments (see p. 74) were more numerous in type four than in type one. Judgments of the first type were decidedly more numerous in the horizontal than in the vertical position while judgments of the second type were markedly and those of the third type slightly more frequent in the vertical position.

A—Comparison of the three sizes of apertures. The medium sized aperture (2 cm.) shows the largest number of identical size and brightness judgments. With this aperture there are the largest number of judgments of the first two types and the smallest number of the third type. In the other apertures the tendency toward identical size and brightness judgments is somewhat more noticeable in the 4 cm. results. The number of identical size and brightness judgments is sensibly equal in the two cases but the number of opposite judgments (third type) is somewhat larger in the 1 cm. than in the 4 cm. aperture, making the 1 cm. aperture the lowest in this respect. The difference between the 2 cm. aperture results and those for the other openings is considerably greater than the difference between the two others.

B—Comparison of the five divergences. The tendency of the size and brightness judgments to coincide, in the different divergences, is most noticeable where the divergence is either 13 cm. or ½ the light diameter, these two being sensibly equal in this respect. It is less noticeable in the divergence which is

2 x the light diameter and least of all in the divergence equal to the light diameter and the o divergence, these two latter being sensibly equal. The difference in the number of identical judgments in the different divergences is extremely slight (a difference of only five between the highest and the lowest) and the order given is made chiefly on the basis of the number of opposite judgments (third type).

TABLE XIX—INDIVIDUAL RESULTS—SUBJECT P.

Distance between lights	Types of judgment	Diameter of lights— 1 cm. Horiz		1 cm. Vert		2 cm. Horiz		2 cm. Vert		4 cm. Horiz		4 cm. Vert		Total of 1, 2 and 4 cm. lights Horiz		Total of 1, 2 and 4 cm. lights Vert	
0 cm.	I	1		7		7		1		7		5		15	25%	13	22%
	II	11		7		5		15		7		8		23	38%	30	50%
	III	8		2		4		4		2		7		14	23%	13	22%
	IV	0		4		4		0		4		0		8	13%	4	7%
½ diameter of light	I	7		5		6		2		5		6		18	30%	13	22%
	II	4		6		5		14		4		10		13	22%	30	50%
	III	4		6		5		3		9		1		18	30%	10	17%
	IV	5		3		4		1		2		3		11	18%	7	12%
= diameter of light	I	5		2		7		0		5		3		17	28%	5	8%
	II	7		12		3		14		10		13		20	33%	39	65%
	III	4		2		4		3		3		2		11	18%	7	12%
	IV	4		4		6		3		2		2		12	20%	9	15%
2 × diameter of light	I	4		4		0		0		4		2		8	13%	6	10%
	II	7		9		9		14		11		9		27	45%	32	53%
	III	5		6		3		2		3		8		11	18%	16	27%
	IV	4		1		8		4		2		1		14	23%	6	10%
13 cm.	I	11		1		10		5		8		6		29	48%	12	20%
	II	6		11		6		8		7		7		19	32%	26	43%
	III	2		4		3		3		2		4		7	12%	11	18%
	IV	1		4		1		4		3		3		5	8%	11	18%
Total	I	28		19		30		8		29		22		87	29%	49	16%
	II	35		45		28		65		39		47		102	34%	157	52%
	III	23		20		19		15		19		22		61	20%	57	19%
	IV	14		16		23		12		13		9		50	17%	37	12%
Total without 13 cm. position	I	17	21%	18	23%	20	25%	3	4%	21	26%	16	20%	58	24%	37	15%
	II	29	36%	34	43%	22	28%	57	71%	32	40%	40	50%	83	34%	131	55%
	III	21	26%	16	20%	16	20%	12	15%	17	21%	18	23%	54	23%	46	19%
	IV	13	16%	12	15%	22	28%	8	10%	10	13%	6	8%	45	19%	26	11%

Discussion of Table XIX

Comparison of size and brightness judgments.

In a majority of cases the two judgments run together (approximately 60 per cent in the horizontal position and 70 per cent in the vertical). The judgments of the second type make up 44 per cent of the total. The opposite judgments (third type) are considerably more numerous than those of the fourth type but less than those of either the first or second type. The judgments of the fourth type are the least numerous, making up less than 15 per cent of the total. The negative judgments (see p. 74) were relatively infrequent. The judgments of the first, third and fourth types were more numerous in the horizontal than in the vertical position, the first and fourth types markedly and the third type slightly so. The judgments of the second type were very decidedly more numerous in the vertical than in the horizontal position.

A—Comparison of the three sizes of apertures. The smallest aperture (1 cm.), shows the smallest number of identical size and brightness judgments. With this aperture there are the smallest number of judgments of the first two types and the largest number of the third type. The other two apertures show an approximately equal tendency of the size and brightness judgments to coincide. The identical judgments are a little more numerous in the 4 cm. aperture but this is compensated for by a correspondingly larger number of opposite judgments (third type) with this aperture. If anything the judgments with the medium aperture show the tendency of the size and brightness judgments to coincide a little more clearly than those with the 4 cm. aperture.

B—Comparison of the five divergences. The tendency of the size and brightness judgments to coincide is most noticeable in the 13 cm. divergence, next in the divergence equal to the light diameter, next in the 0 divergence and least of all in the divergences ½ and 2 x the light diameter, which are sensibly equal in this respect. The difference between the five divergences is not, however, very striking in this respect.

TABLE XX—RESULTS FOR ALL FOUR SUBJECTS TOTALED

Distance between lights	Types of judgment	Diameter of lights— 1 cm. Horiz		1 cm. Vert		2 cm. Horiz		2 cm. Vert		4 cm. Horiz		4 cm. Vert		Total of 1, 2 & 4 cm. lights Horiz		Total of 1, 2 & 4 cm. lights Vert	
0 cm.	I	20		15		23		7		21		21		64	27%	43	18%
	II	40		40		36		58		31		41		107	45%	139	58%
	III	13		5		7		10		11		10		31	13%	25	10%
	IV	7		20		14		5		17		8		38	16%	33	14%
½ diameter of light	I	25		13		27		10		24		14		76	32%	37	15%
	II	34		46		34		57		30		42		98	41%	145	60%
	III	8		9		7		7		14		7		29	12%	23	10%
	IV	13		12		12		6		12		17		37	15%	35	15%
= diameter of light	I	25		11		31		6		19		7		75	31%	24	10%
	II	35		48		22		59		41		52		98	41%	159	66%
	III	7		7		6		8		7		9		20	8%	24	10%
	IV	13		14		21		7		13		12		47	20%	33	14%
2 × diameter of light	I	20		10		23		10		19		13		62	26%	33	14%
	II	32		48		36		58		44		46		112	47%	152	63%
	III	9		15		5		5		4		11		18	8%	31	13%
	IV	19		7		16		7		13		10		48	20%	24	10%
13 cm.	I	23		16		25		28		24		18		72	30%	62	26%
	II	38		47		40		40		36		39		114	48%	126	53%
	III	8		8		6		6		4		8		18	8%	22	9%
	IV	11		9		9		6		16		15		36	15%	30	13%
Total	I	113		65		129		61		107		73		349	29%	199	17%
	II	179		229		168		272		182		220		529	44%	721	60%
	III	45		44		31		36		40		45		116	10%	125	10%
	IV	63		62		72		31		71		62		206	17%	155	13%
Total without 13 cm. position	I	90	28%	49	15%	104	33%	33	10%	83	26%	55	17%	277	29%	137	14%
	II	141	44%	182	57%	128	40%	232	72%	146	46%	181	57%	415	43%	595	62%
	III	37	12%	36	11%	25	8%	30	9%	36	11%	37	12%	98	10%	103	11%
	IV	52	16%	53	17%	63	19%	25	8%	55	17%	47	15%	170	17%	125	13%

Discussion of Tables XVI-XX

Comparison of size and brightness judgments.

Considering all subjects together, the brightness and size judgments coincide in a large majority of cases (over 70 per cent in the horizontal and over 75 per cent in the vertical positions, both for totals with and totals without the 13 cm. divergence results). The judgments of the second type alone make up over half of all the judgments given. The judgments of the third type are much less numerous than any other kind (approximately 10 per cent of the total). The judgments of the first and fourth types are intermediate between those of the second and third types, the first type being more numerous than the fourth. The second type judgments are decidedly more numerous in the vertical than in the horizontal position. The first type is clearly, the fourth type slightly more frequent in the horizontal than in the vertical position. The third type judgments are almost equal for the horizontal and vertical positions.

Considering the four subjects separately, the results of subject P. form an exception to the extremely small number of judgments of the third type given by the four subjects. In his case alone these are not the most infrequent judgments, being more numerous than those of the fourth type. In the case of each individual subject as well as in the totals for all subjects the first type of judgment was more numerous in the horizontal and the second in the vertical position. The fourth type judgments were also more numerous in the horizontal position for each subject as well as in the totals for all subjects. The third type judgments, however, varied with the different subjects, as to predominance in the vertical or horizontal positions. They were for F. about equal in the vertical and horizontal, for P. slightly more numerous in the horizontal, for A. slightly and for H. very decidedly more numerous in the veritcal position.

A—Comparison of the three sizes of apertures. *Considering the totals of all subjects together,* the judgments of size and brightness tend to coincide most frequently in the 2 cm. aperture results. The totals for this sized opening show the greatest

number of identical judgments and the least number of opposite judgments. The 1 cm. and 4 cm. aperture results are practically equal in this respect and both show this characteristic considerably less frequently than the 2 cm. aperture results.

Considering the four subjects separately, the results with the 2 cm. aperture showed this characteristic more clearly than the results with the two other apertures. With subjects A. and H. this difference in favor of the 2 cm. aperture was decided, with subjects P. and F. the difference was slight. The tendency of the size and brightness judgments to coincide was least for subject F. with the 4 cm. aperture, for subjects H. and A. with the 1 cm. aperture and approximately equal with the 1 cm. and 4 cm. apertures for subject P.

B—Comparison of the five divergences. *Considering the totals of all subjects together,* the judgments of size and brightness tend to coincide most frequently with the 13 cm. divergence and decreasingly with the following divergences, divergence equal to light diameter, 2 x light diameter, ½ light diameter and, least of all, in the 0 divergence. The difference between the several divergences in this respect is, however, very slight. It appears more in the difference in the number of judgments of the third type which occur in the various divergences than in a difference in the number of judgments of the first and second types.

Considering the four subjects separately, there is relatively little uniformity in the order of divergences with regard to the tendency of the size and brightness judgments to coincide. The divergence equal to the light diameter for instance, shows this characteristic most clearly for subject H., is second in order for subject A. and shows it least noticeably for subjects P. and F. The nearest approach to uniformity among the three subjects is in regard to the 13 cm. divergence. This shows the characteristic in question most clearly for subjects P. and A. and is second in order for subject H.

Sets of Control Experiments

Second Series (Control I)

The effort here was to discover whether, with lights given in the diagonal positions instead of the horizontal and vertical, the tendency to favor the lower light or the tendency to favor the right or left light; or on the other hand, to judge these latter as predominately equal, would dominate the results. Considering the results of all subjects taken together, the judgments on brightness showed a decided tendency to favor the lower light in both diagonal positions, irrespective of whether this was also the right or left light. The preference was strongest when the lower light was also the left light, showing the influence of the strong preference for the left of subject P. The size judgments failed to run parallel with the brightness judgments. They favored the left hand light in both diagonal positions, irrespective of whether it was the upper or lower light. The preference was stronger, however, when the light was both lower and left. This was also conditioned chiefly by the strong preference for the left, of subject P. With the individual subjects the brightness judgments of two (F. and H.) were dominated by the preference for the lower light, this being chosen whether it was left or right. It was stronger where the two preferences coincided, *i.e.* when the light was both lower and left. With the other two subjects the horizontal preference dominated the results, in one case (C.) the right and in the other (P.) the left being chosen in both diagonal positions, irrespective of whether it was the upper or lower. It was strongest, for both of these subjects, when the two types of preference coincided—with C., when the light was both lower and right and with P., when the light was both lower and left. In size judgments the results of P. and H. paralleled the brightness judgments, being dominated in the case of the former by the preference for the left hand light and in the case of the latter by the preference for the lower. With subject F., where the two types of preference "collided" in certain judgments they practically neutralize each other, *i.e.* in judg-

ments between upper-left and lower-right. With subject C. the preference for the lower light dominated the size results, whereas, in the brightness results of this subject, the horizontal preference for the right had done so. Subject H. is, therefore, the only one whose results show the preference for the lower light dominating both the size and brightness results while in subject P. the preference for the left light was the dominant factor in both size and brightness judgments. In the latter case alone is a definite size preference shown for the upper light, being stronger when the light was both upper and left than when it was lower and left. An illuminating comment was made in the introspection of the four subjects. It was reported that they *thought of the lights as still in the horizontal-vertical positions* instead of in the diagonal positions in which, actually, they were shown. One diagonal was accepted as the vertical and the other as the horizontal and this relation was maintained throughout the series of experiments with the oblique judgments. From this point of view the lower light *was* predominantly chosen in the "vertical" position, *i.e.* in that diagonal *thought* of as the vertical, and what appeared in many cases as a judgment favoring the upper light was really a judgment showing the subject's preference for one of the lights in what he was thinking of as the horizontal position. In the case of subject P. alone the preference for one of the lights in this "imaginary horizontal" position was greater than that for the "lower" light in the "vertical." In the first (main) set of judgments with this apparatus his preference for the left hand light had more nearly approximated his preference for the lower than had the horizontal preferences of any of the other subjects—though it had never exceeded the vertical preference as, apparently, it did in this case. F.'s judgments on size with the oblique positions, showing a normal preference for the lower where it was also the left but a practical equality of judgments where the lower was also the right was, according to this interpretation, really her normal judgment of preference for the lower light with practical equality in the "horizontal" judgments. The same was true for the judgments of H. and C. With them

the size judgments in the oblique position regarded as "horizontal" closely approximated equality and the brightness judgments in the same position were very much reduced in inequality. The apparent effect, on the character of the results, of this attitude toward the lights, is particularly striking, as an actual rotation of the head, sufficient to make the lights vertical and horizontal for the eyes, *i.e.* a rotation through 45 degrees, was wholly impossible. The rotation of the head, possible without cutting off the view of the lights, was less than 3 degrees. (See discussion of this point in the conclusion.)

Third Series (*Control II*)

The only fact brought out in this control series is that the phenomenon is perfectly evident with binocular as well as with monocular vision. It was somewhat less striking, both for the individual subjects and in the results for all subjects taken together, and there was a slightly larger number of judgments favoring the right or left light but the phenomenon was clearly apparent throughout and appeared with about the same relative importance for the different subjects as in the main series with this apparatus (right eye only).

Fourth Series (*Control III*)

In this series of judgments, with the left eye, the phenomenon appears in a manner quite comparable with the results of the main series with this apparatus, made with the right eye. This applies both to the results of the individual subjects and to the results of all subjects taken together. The one possible exception is in the case of the subject P., with whom the phenomenon appeared somewhat more clearly in this series than in the main series. His judgments favoring the lower light were more numerous in this series and the judgments in the horizontal position more closely approached equality. Such preference as was shown, however, in the horizontal position was in the same direction as in the main series of results with the right eye, viz. in favor of the left light.

Fifth Series (Control IV)

The particular object of this series, with a permanent fixation, was to determine whether or not the order in which the lights were fixated or the direction from which the eye moved to the different lights had any important influence on the appearance of the phenomenon. While the fixation of the subject's eye was established in this series midway between the two lights before they were exposed and this fixation was held after the exposure, the judgments were not strictly made by indirect vision as the divergences used were sufficiently small so that, with a fixation midway between the two lights, they could both be seen in direct vision. For three of the subjects the results were, on the whole, quite comparable with those of the main series, with the exception that, for subject C., the size judgments were almost wholly judgments of equality. The phenomenon was not, to be sure, as noticeable as in the main series, the preferences in the horizontal position being relatively more numerous and those for the lower light, in the vertical position, relatively less numerous. The phenomenon was, however, perfectly apparent and the preference in the horizontal position was the same, for each subject, as in the previous series. With subject P. the preference in the vertical position was reversed, the upper light being favored. This preference did not, however, equal that for the left light in the horizontal position.

Sixth Series (Control V)

In this series, with eccentric fixation, the phenomenon appeared with only one subject (C.) and in this case only in the brightness judgments and to the very slightest extent, the preference for the right being practically equal to that for the lower light. With the three other subjects a partial or complete reversal took place in the vertical judgments, the upper light being somewhat more frequently favored than the lower, at least in brightness judgments. With subjects F. and H. this occurred both with the fixation at the left and at the right. With subject F. it was more striking with the fixation at the left and with subject H. with the

fixation at the right. With both subjects it was paralleled by a greater preference for one of the lights in the horizontal position. With subject P. the upper light was very slightly preferred when the fixation point was at the left and the lower when the fixation point was at the right. There was in his case, a very much more striking preference for the left hand light, both with the fixation point above and below. Subject F. alone gave any judgments of inequality in size. They were relatively small in number and, when reported, followed the brightness judgments closely. The lights were uniformly judged of equal size by subject C. in this series and all size judgments were reported as impossible by P. and H. It was evident from the introspective account that the uniform judgments of equality in size, given by subject C., were practically equivalent to a statement that judgments on size were impossible rather than to a definite and positive judgment of equality. They, were, that is, negative judgments. The results with this series are practically negative, the phenomenon appearing with only one subject and there to the very slightest extent and accompanied by an approximately equal preference for one of the lights in the horizontal position.

Seventh Series (Control VI)

In this series four divergences were used which were intermediate between those which showed the phenomenon most clearly in the main series with this apparatus and the smallest divergence used on the second apparatus. In the brightness judgments of all subjects taken together the phenomenon appears to a small extent in the 8 cm. divergence but is paralleled by a greater preference for the left light in the horizontal position. It appears somewhat more clearly in the 13 cm. divergence and without an equal preference for one of the horizontal lights. The reverse preference, for the upper light, is shown in the 18 cm. divergence and the same appears to a slight extent in the 24 cm. divergence with practical equality in the horizontal judgments. The size judgments show a very much larger number of equal judgments throughout and, in the three larger divergences, show no preference for either of the lights in the

vertical position. They are also sensibly equal in the horizontal position, with a slight preference for the left in the 8, 12 and 24 cm. divergences and for the right in the 18 cm. The separate results of the individual subjects do not show any very striking variation from these totals of all subjects. In general they show the phenomenon very slightly or not at all in the larger divergences and paralleled, in the horizontal position, by equally or by more striking preferences for the right or left hand lights. The number of equality judgments in the larger divergences is relatively great, particularly in the vertical position. The one noticeable exception to this is subject P. whose results showed no preference in the vertical position with the 13 cm. divergence but a fairly well marked preference for the upper light with the 18 cm. and 24 cm. divergences and a relatively small number of equality judgments in either the horizontal or vertical positions throughout the four divergences. Practically the phenomenon in question does not occur with the 18 cm. and 24 cm. divergences or, at most, in the slightest degree only and with little uniformity.

Eighth Series (*Control VII*)

In this series additional screens were used behind one of the lights. These screens were of such a thickness that, when twenty were placed behind one light and none behind the other, the latter was twice as bright as the former by photometric measurement. With subjects H., F. and P. several errors were made when one light had one screen and the other none. The unscreened light was not uniformly judged the brighter. With two screens behind one opening and none behind the other only one error was made by these subjects (by H.). With subject C. several errors were made with two screens behind one opening and none behind the other. The 2 cm. apertures were used and set at the divergence equal to the light diameter (2 cm.). (For relative brightness of the two lights in the four positions, see diagram attached to table 51, p. 115.) The lights were shown six times in the vertical and six times in the horizontal positions for each color and with each degree of screening. Of the thirty-two

misjudgments made, fifteen were cases where the lower, though actually the dimmer, was judged to be the brighter and two were cases where the upper and lower were judged equally bright though the lower was the dimmer. In only two cases was the upper, when actually dimmer, judged to be brighter. In the other thirteen cases the two lights in the horizontal position, though actually unequal, were judged to be equal. In the majority of the cases this misjudgment was in the direction of the subject's normal choice in the horizontal position (as shown in the judgments of the other series). The amount of difference in the two lights which was, with considerable frequency, overlooked by three of the subjects was, therefore, less than one twentieth of one light. It was probably less than this fraction for subject C. also but was larger than for the other subjects. When such difference in actual brightness was overlooked, it predominantly favored the lower light.

Third Apparatus, second series (Control I). Object lights diagonally placed

Two parts are given for each table. In one the judgments are classified as "right" or "left" (first part of table, headed R-L). In the other they are classified as "upper" or "lower" (second part of table, headed U-L). Three colors were used; Yellow, Green and Red. In the second line of these tables, the numbers 1, 2, 3 and 4 represent the four positions in which each light was shown. Thus, the columns headed "1-3" give the judgments made when one of the lights was upper and right, the other lower and left. Three divergences were used: only one aperture (2 cm.).

R-L

TABLE XXI—Individual Results—Subject F.

Divergence		Y						G						R						Total					
		1 – 3			2 – 4			1 – 3			2 – 4			1 – 3			2 – 4			1 – 3			2 – 4		
		U	=	L	U	=	L	U	=	L	U	=	L	U	=	L	U	=	L	U	=	L	U	=	L
1 cm.	B	0	9	3	0	8	4	0	0	12	2	6	4	0	5	7	0	6	6	0	14	22	2	20	14
	S	0	8	4	7	5	0	0	8	4	4	2	6	2	6	4	2	10	0	2	22	12	13	17	6
2 cm.	B	0	12	0	0	12	0	0	6	6	1	11	0	0	2	10	1	11	0	0	20	16	2	34	0
	S	0	9	3	0	12	0	2	5	5	0	10	2	0	11	1	2	10	0	2	23	11	2	32	2
4 cm.	B	0	5	7	0	12	0	2	8	2	0	12	0	0	2	10	0	6	6	2	15	19	0	30	6
	S	0	8	4	0	9	3	4	8	0	0	12	0	0	8	4	0	9	3	4	24	8	0	30	6
Total	B	0	26	10	0	32	4	2	14	20	3	29	4	0	9	27	1	23	12	2	49	57	4	84	20
	S	0	25	11	7	26	3	6	21	9	4	24	8	2	25	9	4	29	3	8	69	31	15	79	14

U-L

TABLE XXI—Individual Results—Subject F.—(*Continued*)

Divergence		Y						G						R						Total					
		1 – 3			2 – 4			1 – 3			2 – 4			1 – 3			2 – 4			1 – 3			2 – 4		
		R	=	L	R	=	L	R	=	L	R	=	L	R	=	L	U	=	L	R	=	L	U	=	L
1 cm.	B	0	9	3	4	8	0	0	0	12	4	6	2	0	5	7	6	6	0	0	14	22	14	20	2
	S	0	8	4	0	5	7	0	8	4	6	2	4	2	6	4	0	10	2	2	22	12	6	17	13
2 cm.	B	0	12	0	0	12	0	0	6	6	0	11	1	0	2	10	0	11	1	0	20	16	0	34	2
	S	0	9	3	0	12	0	2	5	5	2	10	0	0	11	1	0	10	2	2	23	11	2	32	2
4 cm.	B	0	5	7	0	12	0	2	8	2	0	12	0	0	2	10	6	6	0	2	15	19	6	30	0
	S	0	8	4	3	9	0	4	8	0	0	12	0	0	8	4	3	9	0	4	24	8	6	30	0
Total	B	0	26	10	4	32	0	2	14	20	4	29	3	0	9	27	12	23	1	2	49	57	20	84	4
	S	0	25	11	3	26	7	6	21	9	8	24	4	2	25	9	3	29	4	8	69	31	14	79	15

R-L

TABLE XXII—INDIVIDUAL RESULTS—SUBJECT H

Divergence		Y						G						R						Total					
		R^{1-3}	=	L	R^{2-4}	=	L	R^{1-3}	=	L	R^{2-4}	=	L	R^{1-3}	=	L	R^{2-4}	=	L	R^{1-3}	=	L	R^{2-4}	=	L
1 cm.	B	1	5	6	7	3	2	0	6	6	4	5	3	0	4	8	4	8	0	1	15	20	15	16	5
	S	0	6	6	5	5	2	1	5	6	3	6	3	1	4	7	2	8	2	2	15	19	10	19	7
2 cm.	B	0	0	12	1	8	3	1	7	4	0	12	0	1	8	3	2	8	2	2	15	19	3	28	5
	S	0	0	12	1	9	2	2	5	5	1	11	0	0	8	4	2	10	0	2	13	21	4	30	2
4 cm.	B	1	5	6	2	9	1	0	9	3	1	9	2	1	10	1	1	9	2	2	24	10	4	27	5
	S	2	7	3	2	9	1	0	10	2	1	8	3	1	11	0	1	8	3	3	28	5	4	25	7
Total	B	2	10	24	10	20	6	1	22	13	5	26	5	2	22	12	7	25	4	5	54	49	22	71	15
	S	2	13	21	8	23	5	3	20	13	5	25	6	2	23	11	5	26	5	7	56	45	18	74	16

U-L

TABLE XXII—INDIVIDUAL RESULTS—SUBJECT H.—(*Continued*)

Divergence		Y						G						R						Total					
		U^{1-3}	=	L	U^{2-4}	=	L	U^{1-3}	=	L	U^{2-4}	=	L	U^{1-3}	=	L	U^{2-4}	=	L	U^{1-3}	=	L	U^{2-4}	=	L
1 cm.	B	1	5	6	2	3	7	0	6	6	3	5	4	0	4	8	0	8	4	1	15	20	5	16	15
	S	0	6	6	2	5	5	1	5	6	3	6	3	1	4	7	2	8	2	2	15	19	7	19	10
2 cm.	B	0	0	12	3	8	1	1	7	4	0	12	0	1	8	3	2	8	2	2	15	19	5	28	3
	S	0	0	12	2	9	1	2	5	5	0	11	1	0	8	4	0	10	2	2	13	21	2	30	4
4 cm.	B	1	5	6	1	9	2	0	9	3	2	9	1	1	10	1	2	9	1	2	24	10	5	27	4
	S	2	7	3	1	9	2	0	10	2	3	8	1	1	11	0	3	8	1	3	28	5	7	25	4
Total	B	2	10	24	6	20	10	1	22	13	5	26	5	2	22	12	4	25	7	5	54	49	15	71	22
	S	2	13	21	5	23	8	3	20	13	6	25	5	2	23	11	5	26	5	7	56	45	16	74	18

TABLE XXIII—Individual Results—Subject C.

R-L

Divergence		Y 1–3 R	Y 1–3 =	Y 1–3 L	Y 2–4 R	Y 2–4 =	Y 2–4 L	G 1–3 R	G 1–3 =	G 1–3 L	G 2–4 R	G 2–4 =	G 2–4 L	R 1–3 R	R 1–3 =	R 1–3 L	R 2–4 R	R 2–4 =	R 2–4 L	Total 1–3 R	Total 1–3 =	Total 1–3 L	Total 2–4 R	Total 2–4 =	Total 2–4 L
1 cm.	B	4	5	3	9	3	0	4	5	3	5	4	3	2	8	2	7	4	1	10	18	8	21	11	4
	S	0	12	0	0	11	1	0	11	1	0	12	0	0	11	1	2	10	0	0	34	2	2	33	1
2 cm.	B	8	4	0	4	3	5	5	5	2	5	5	2	2	6	4	8	4	0	15	15	6	17	12	7
	S	0	7	5	3	8	1	2	7	3	3	8	1	0	8	4	2	9	1	2	22	12	8	25	3
4 cm.	B	3	6	3	9	3	0	2	6	4	12	0	0	6	4	2	8	3	1	11	16	9	29	6	1
	S	2	10	0	1	11	0	3	9	0	5	7	0	2	8	2	0	10	2	7	27	2	6	28	2
Total	B	15	15	6	22	9	5	11	16	9	22	9	5	10	18	8	23	11	2	36	49	23	67	29	12
	S	2	29	5	4	30	2	5	27	4	8	27	1	2	27	7	4	29	3	9	83	16	16	86	6

TABLE XXIII—Individual Results—Subject C.—(*Continued*)

U-L

Divergence		Y 1–3 U	Y 1–3 =	Y 1–3 L	Y 2–4 U	Y 2–4 =	Y 2–4 L	G 1–3 U	G 1–3 =	G 1–3 L	G 2–4 U	G 2–4 =	G 2–4 L	R 1–3 U	R 1–3 =	R 1–3 L	R 2–4 U	R 2–4 =	R 2–4 L	Total 1–3 U	Total 1–3 =	Total 1–3 L	Total 2–4 U	Total 2–4 =	Total 2–4 L
1 cm.	B	2	0	10	10	0	2	3	0	9	6	2	4	7	2	3	6	3	3	12	2	22	22	5	9
	S	2	0	10	11	0	1	0	2	10	5	2	5	6	3	3	8	2	2	8	5	23	24	4	8
2 cm.	B	3	0	9	9	1	2	2	8	2	7	3	2	5	4	3	10	2	0	10	12	14	26	6	4
	S	4	0	8	8	2	2	2	7	3	8	4	0	6	5	1	10	2	0	12	12	12	26	8	2
4 cm.	B	0	0	12	3	3	6	10	2	0	10	1	1	4	2	6	7	1	4	14	4	18	20	5	11
	S	9	0	3	6	3	3	8	4	0	6	4	2	3	2	7	7	1	4	20	6	10	19	8	9
Total	B	5	0	31	22	4	10	15	10	11	23	6	7	16	8	12	23	6	7	36	18	54	68	16	24
	S	15	0	21	25	5	6	10	13	13	19	10	7	15	10	11	25	5	6	40	23	45	69	20	19

TABLE XXIV—Individual Results—Subject P.

R-L

Divergence		Y 1-3 R	=	L	Y 2-4 R	=	L	G 1-3 R	=	L	G 2-4 R	=	L	R 1-3 R	=	L	R 2-4 R	=	L	Total 1-3 R	=	L	Total 2-4 R	=	L
1 cm.	B	2	0	10	2	0	10	3	0	9	4	2	6	7	2	3	3	3	6	12	2	22	9	5	22
	S	2	0	10	1	0	11	0	2	10	5	2	5	6	3	3	2	2	8	8	5	23	8	4	24
2 cm.	B	3	0	9	2	1	9	2	8	2	2	3	7	5	4	3	0	2	10	10	12	14	4	6	26
	S	4	0	8	2	2	8	2	7	3	0	4	8	6	5	1	0	2	10	12	12	12	2	8	26
4 cm.	B	0	0	12	6	3	3	10	2	0	1	1	10	4	2	6	4	1	7	14	4	18	11	5	20
	S	9	0	3	3	3	6	8	4	0	2	4	6	3	2	7	4	1	7	20	6	10	9	8	19
Total	B	5	0	31	10	4	22	15	10	11	7	6	23	16	8	12	7	6	23	36	18	54	24	16	68
	S	15	0	21	6	5	25	10	13	13	7	10	19	15	10	11	6	5	25	40	23	45	19	20	69

TABLE XXIV—Individual Results—Subject P.—(*Continued*)

U-L

Divergence		Y 1-3 U	=	L	Y 2-4 U	=	L	G 1-3 U	=	L	G 2-4 U	=	L	R 1-3 U	=	L	R 2-4 U	=	L	Total 1-3 U	=	L	Total 2-4 U	=	L
1 cm.	B	4	5	3	0	3	9	4	5	3	3	4	5	2	8	2	1	4	7	10	18	8	4	10	21
	S	0	12	0	1	11	0	0	11	1	0	12	0	0	11	1	0	10	2	0	34	2	1	33	2
2 cm.	B	8	4	0	5	3	4	5	5	2	2	5	5	2	6	4	0	4	8	15	15	6	7	12	17
	S	0	7	5	1	8	3	2	7	3	1	8	3	0	8	4	1	9	2	2	22	12	3	25	8
4 cm.	B	3	6	3	0	3	9	2	6	4	0	0	12	6	4	2	1	3	8	11	16	9	1	6	29
	S	2	10	0	0	11	1	3	9	0	0	7	5	2	8	2	2	10	0	7	27	2	2	28	6
Total	B	15	15	6	5	9	22	11	16	9	5	9	22	10	18	8	2	11	23	36	49	23	12	29	67
	S	2	29	5	2	30	4	5	27	4	1	27	8	2	27	7	3	29	4	9	83	16	6	86	16

TABLE XXV—Results for all four subjects

Divergence		R - L All colors combined 1 - 3			R - L All colors combined 2 - 4			U - L All colors combined 1 - 3			U - L All colors combined 2 - 4	
		R	=	L	R	=	L	U	=	L	U	=
1 cm.	B	23	49	72	59	52	33	23	49	72	33	52
	S	12	76	56	26	73	45	12	76	56	45	73
2 cm.	B	27	62	55	24	80	40	27	62	55	40	80
	S	18	70	56	16	95	33	18	70	56	33	95
4 cm.	B	29	59	56	50	68	26	29	59	56	26	68
	S	34	85	25	25	91	28	34	85	25	28	91
Total	B	79	170	183	133	200	99	79	170	183	99	200
	S	64	231	137	67	259	106	64	231	137	106	259

Third Apparatus, third series (Control II). Binocular vision. Three colors, three divergences; aperture (2 cm.).

TABLE XXVI—INDIVIDUAL RESULTS—SUBJECT F.

Divergence		Y						G						R						Total					
		Horiz			Vert			Horiz			Vert			Horiz			Vert			Horiz			Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
1 cm.	B	3	9	0	4	4	4	1	8	3	0	5	7	2	8	2	0	2	10	6	25	5	4	11	21
	S	0	12	0	0	7	5	0	9	3	0	7	5	0	8	4	0	12	0	0	29	7	0	26	10
2 cm.	B	0	8	4	1	3	8	0	10	2	1	5	6	3	5	4	2	2	8	3	23	10	4	10	22
	S	3	3	6	0	4	8	1	11	0	0	8	4	0	9	3	1	11	0	4	23	9	1	23	12
4 cm.	B	2	8	2	0	5	7	2	10	0	0	4	8	0	6	6	0	3	9	4	24	8	0	12	24
	S	4	4	4	0	6	6	4	7	1	0	2	10	0	11	1	1	10	1	8	22	6	1	18	17
Total	B	5	25	6	5	12	19	3	28	5	1	14	21	5	19	12	2	7	27	13	72	23	8	33	67
	S	7	19	10	0	17	19	5	27	4	0	17	19	0	28	8	2	33	1	12	74	22	2	67	39

TABLE XXVII—INDIVIDUAL RESULTS—SUBJECT H.

Divergence		Y						G						R						Total					
		Horiz			Vert			Horiz			Vert			Horiz			Vert			Horiz			Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
1 cm.	B	0	12	0	0	3	9	3	8	1	1	4	7	0	10	2	0	4	8	3	30	3	1	11	24
	S	0	12	0	1	3	8	3	9	0	1	6	5	0	10	2	0	5	7	3	31	2	2	14	20
2 cm.	B	2	10	0	1	2	9	1	9	2	2	6	4	2	9	1	0	7	5	5	28	3	3	15	18
	S	1	10	1	0	3	9	3	7	2	2	7	3	2	8	2	2	6	4	6	25	5	4	16	16
4 cm.	B	1	9	2	1	6	5	6	5	1	1	7	4	3	8	1	1	6	5	10	22	4	3	19	14
	S	2	8	2	0	6	6	3	8	1	0	9	3	2	8	2	1	7	4	7	24	5	1	22	13
Total	B	3	31	2	2	11	23	10	22	4	4	17	15	5	27	4	1	17	18	18	80	10	7	45	56
	S	3	30	3	1	12	23	9	24	3	3	22	11	4	26	6	3	18	15	16	80	12	7	52	49

TABLE XXVIII—INDIVIDUAL RESULTS—SUBJECT C.

Divergence		Y						G						R						Total					
		Horiz			Vert			Horiz			Vert			Horiz			Vert			Horiz			Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
1 cm.	B	0	12	0	3	3	6	7	5	0	0	0	12	2	10	0	3	0	9	9	27	0	6	3	27
	S	0	12	0	0	11	1	0	12	0	0	10	2	3	9	0	0	8	4	3	33	0	0	29	7
2 cm.	B	0	9	3	3	4	5	0	12	0	9	3	0	3	9	0	3	2	7	4	30	2	15	9	12
	S	1	11	0	0	12	0	0	12	0	3	9	0	2	10	0	0	11	1	3	33	0	3	32	1
4 cm.	B	1	3	8	4	2	6	6	6	0	0	4	8	1	7	4	0	2	10	8	16	12	4	8	24
	S	0	12	0	2	5	5	0	12	0	0	9	3	0	12	0	0	10	2	0	36	0	2	24	10
Total	B	1	24	11	10	9	17	13	23	0	9	7	20	6	26	4	6	4	26	21	73	14	25	20	63
	S	1	35	0	2	28	6	0	36	0	3	28	5	5	31	0	0	29	7	6	102	0	5	85	18

TABLE XXIX—INDIVIDUAL RESULTS—SUBJECT P.

Divergence		Y						G						R						Total					
		Horiz			Vert			Horiz			Vert			Horiz			Vert			Horiz			Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
1 cm.	B	2	3	7	0	0	12	0	0	12	0	0	12	4	0	8	0	0	12	6	3	27	0	0	36
	S	0	2	10	0	0	12	0	1	11	0	0	12	3	0	9	0	0	12	3	3	30	0	0	36
2 cm.	B	0	4	8	0	2	10	3	6.	3	0	1	11	6	3	3	0	0	12	9	13	14	0	3	33
	S	0	1	11	0	3	9	3	4	5	0	0	12	6	4	2	0	1	11	9	10	17	0	4	32
4 cm.	B	3	0	9	6	1	5	6	0	6	5	0	7	9	3	0	1	3	8	15	3	18	12	4	20
	S	3	0	9	5	0	7	1	3	8	0	0	12	3	0	9	1	5	6	7	3	26	6	5	25
Total	B	5	7	24	6	3	27	9	6	21	5	1	30	19	6	11	1	3	32	30	19	59	12	7	89
	S	3	3	30	5	3	28	4	9	23	0	0	36	12	4	20	1	6	29	19	16	72	6	9	93

TABLE XXX—Results of all four subjects together

Divergence		Horiz R	Horiz =	Horiz L	Vert U	Vert =	Vert L
1 cm.	B	24	85	35	11	25	108
	S	9	96	39	2	69	73
2 cm.	B	21	94	29	22	37	85
	S	22	91	31	8	75	61
4 cm.	B	37	65	42	19	43	82
	S	22	85	37	10	69	65
Total	B	82	244	106	52	105	275
	S	53	272	106	20	213	199

Third Apparatus, fourth series (Control III). Left eye. Three colors, three divergences, one aperture (2 cm.)

TABLE XXXI—INDIVIDUAL RESULTS—SUBJECT F.

Divergence		Y						G						R						Total					
		Horiz			Vert			Horiz			Vert			Horiz			Vert			Horiz			Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
1 cm.	B	6	0	6	1	4	7	5	2	5	1	2	9	4	4	4	0	3	9	15	6	15	2	9	25
	S	4	7	1	2	4	6	4	5	3	0	4	8	3	5	4	0	4	8	11	17	8	2	12	22
2 cm.	B	0	9	3	9	1	2	0	12	0	0	0	12	2	10	0	0	0	12	17	7	12	9	1	26
	S	1	8	3	0	5	7	0	12	0	0	12	0	3	8	1	0	12	0	4	28	4	0	29	7
4 cm.	B	2	7	3	1	1	10	4	3	5	4	0	8	4	7	1	0	0	12	10	17	9	5	1	30
	S	3	8	1	3	2	7	2	9	1	0	3	9	1	8	3	0	5	7	6	25	5	3	10	23
Total	B	10	16	10	4	11	21	7	23	6	1	17	18	8	20	8	0	20	16	42	30	36	16	11	81
	S	8	23	5	5	11	20	6	26	4	0	19	17	7	21	8	0	21	15	21	70	17	5	51	52

TABLE XXXII—INDIVIDUAL RESULTS—SUBJECT H.

Divergence		Y						G						R						Total					
		Horiz			Vert			Horiz			Vert			Horiz			Vert			Horiz			Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
1 cm.	B	7	1	4	2	3	7	5	1	6	2	5	5	5	3	4	2	2	8	17	5	14	6	10	20
	S	6	2	4	2	3	7	4	3	5	2	5	5	4	3	5	3	3	6	14	8	14	7	11	18
2 cm.	B	2	10	0	0	0	12	5	6	1	3	2	7	2	3	7	0	4	8	9	19	8	3	6	27
	S	2	10	0	1	0	11	5	4	3	4	2	6	2	3	7	0	5	7	9	17	10	5	7	24
4 cm.	B	2	7	3	0	6	6	4	7	1	1	3	8	3	7	2	0	2	10	9	21	6	1	11	24
	S	2	8	2	2	4	6	2	10	0	2	2	8	2	7	3	0	2	10	6	25	5	4	8	24
Total	B	11	18	7	2	9	25	14	14	8	6	10	20	10	13	13	2	8	26	35	45	28	10	27	71
	S	10	20	6	5	7	24	11	17	8	8	9	19	8	13	15	3	10	23	29	50	29	16	26	66

TABLE XXXIII—Individual Results—Subject C.

Divergence		Y						G						R						Total					
		Horiz			Vert			Horiz			Vert			Horiz			Vert			Horiz			Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
1 cm.	B	2	4	6	4	0	8	4	4	4	1	3	8	4	8	0	0	0	12	10	16	10	5	3	28
	S	5	5	2	5	0	7	5	5	2	2	3	7	2	5	5	3	0	9	12	15	9	10	3	23
2 cm.	B	0	12	0	0	8	4	2	10	0	0	3	9	5	0	7	7	0	5	7	22	7	7	11	18
	S	2	10	0	3	3	6	0	10	2	3	3	6	0	11	1	3	3	6	2	31	3	9	9	18
4 cm.	B	2	10	0	1	3	8	0	8	4	0	1	11	3	9	0	0	2	10	5	27	4	1	6	29
	S	3	9	0	1	7	4	3	5	4	2	0	10	2	6	4	2	1	9	8	20	8	5	8	23
Total	B	4	26	6	5	11	20	6	22	8	1	7	28	12	17	7	7	2	27	22	65	21	13	20	75
	S	10	24	2	9	19	17	8	20	8	7	6	23	4	22	10	8	4	24	22	66	20	24	20	64

TABLE XXXIV—Individual Results—Subject P.

Divergence		Y						G						R						Total					
		Horiz			Vert			Horiz			Vert			Horiz			Vert			Horiz			Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
1 cm.	B	3	6	3	0	0	12	3	5	4	2	0	10	4	5	3	5	1	6	10	16	10	7	1	28
	S	2	6	4	4	5	3	2	6	4	2	0	10	3	7	2	0	0	12	7	19	10	6	5	25
2 cm.	B	6	3	3	0	0	12	2	4	6	4	0	8	3	3	6	0	0	12	11	10	15	4	0	32
	S	2	4	6	0	0	12	5	1	6	0	0	12	0	0	12	0	0	12	7	5	24	0	0	36
4 cm.	B	1	8	3	1	3	8	3	7	2	0	0	12	3	6	3	4	0	8	7	21	8	5	3	28
	S	4	4	4	4	4	4	4	4	4	5	3	4	4	4	4	1	0	11	12	12	12	10	7	19
Total	B	10	17	9	1	3	32	8	16	12	6	0	30	10	14	12	9	1	26	28	47	33	16	4	88
	S	8	14	14	8	9	19	11	11	14	7	3	26	7	11	18	1	0	35	26	36	46	16	12	80

TABLE XXXV—Results of all Four Subjects Together

Divergence		Horiz R	Horiz =	Horiz L	Vert U	Vert =	Vert L
1 cm.	B	52	43	49	20	23	101
	S	44	59	41	25	31	88
2 cm.	B	44	58	42	23	18	103
	S	22	81	41	14	45	85
4 cm.	B	31	86	27	12	21	111
	S	32	82	30	22	33	89
Total	B	128	187	118	55	62	315
	S	98	222	112	61	109	262

Third Apparatus, fifth series (Control IV). Permanent Central fixation. Three colors, three divergences, one aperture (2 cm.)

TABLE XXXVI—Individual Results—Subject F.

Divergence		Y						G						R						Total					
		Horiz			Vert			Horiz			Vert			Horiz			Vert			Horiz			Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
1 cm.	B	3	1	8	3	9	0	0	11	1	0	6	6	0	3	9	3	0	9	3	15	18	6	15	15
	S	0	12	0	0	12	0	1	11	0	0	6	6	4	8	0	3	9	0	5	31	0	3	27	6
2 cm.	B	6	0	6	0	2	10	3	6	3	0	4	8	1	5	6	1	2	9	10	11	15	1	8	27
	S	6	6	0	0	7	5	3	9	0	0	8	4	0	12	0	0	9	3	9	27	0	0	24	12
4 cm.	B	1	5	6	3	0	9	0	3	9	0	0	12	4	5	3	2	1	9	5	13	18	5	1	30
	S	1	8	3	0	5	7	9	3	0	0	6	6	9	3	0	0	10	2	19	14	3	0	21	15
Total	B	10	6	20	6	11	19	3	20	13	0	10	26	5	13	18	6	3	27	18	39	51	12	24	72
	S	7	26	3	0	24	12	13	23	0	0	20	16	13	23	0	3	28	5	33	72	3	3	72	33

TABLE XXXVII—Individual Results—Subject H.

Divergence		Y						G						R						Total					
		Horiz			Vert			Horiz			Vert			Horiz			Vert			Horiz			Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
1 cm.	B	6	4	2	2	3	7	4	4	4	3	4	5	8	4	0	2	5	5	18	12	6	7	12	17
	S	4	5	3	2	5	5	4	4	4	3	7	2	5	7	0	0	10	2	13	16	7	5	22	9
2 cm.	B	1	11	0	1	7	4	5	6	1	0	2	10	4	2	6	4	1	7	10	19	7	5	10	21
	S	3	9	0	1	10	1	3	6	3	2	7	3	3	4	5	0	6	6	9	19	8	3	23	10
4 cm.	B	5	4	3	1	1	10	0	7	5	3	6	3	6	5	1	2	1	9	11	16	9	6	8	22
	S	0	9	3	1	5	6	2	7	3	0	12	0	3	9	0	0	5	7	5	25	6	1	22	13
Total	B	12	19	5	4	11	21	9	17	10	6	12	18	18	11	7	8	7	21	39	47	22	18	30	60
	S	7	23	6	4	20	12	9	17	10	5	26	5	11	20	5	0	21	15	27	60	21	9	67	32

TABLE XXXVIII—Individual Results—Subject C.

Divergence		Y						G						R						Total					
		Horiz			Vert			Horiz			Vert			Horiz			Vert			Horiz			Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
1 cm.	B	12	0	0	8	1	3	9	3	0	6	0	6	1	11	0	0	11	1	21	15	0	15	11	10
	S	0	12	0	0	12	0	0	12	0	0	12	0	0	12	0	0	12	0	0	36	0	0	36	0
2 cm.	B	4	8	0	0	4	8	2	7	3	3	7	2	4	8	0	0	2	10	10	23	3	3	13	20
	S	0	12	0	0	12	0	0	12	0	0	9	3	0	12	0	0	12	0	0	36	0	0	33	3
4 cm.	B	7	2	3	6	0	6	2	10	0	0	3	9	5	4	3	3	0	9	14	16	6	9	3	24
	S	0	12	0	0	12	0	0	12	0	0	12	0	0	12	0	0	12	0	0	36	0	0	36	0
Total	B	23	10	3	14	5	17	13	20	3	9	10	17	10	23	3	3	13	20	45	54	9	27	27	54
	S	0	36	0	0	36	0	0	36	0	0	33	3	0	36	0	0	36	0	0	108	0	0	105	3

TABLE XXXIX—Individual Results—Subject P.

Divergence		Y						G						R						Total					
		Horiz			Vert			Horiz			Vert			Horiz			Vert			Horiz			Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
1 cm.	B	0	3	9	5	3	4	0	0	12	6	4	2	3	1	8	10	0	2	3	4	29	21	7	8
	S	0	0	12	3	0	9	1	0	11	7	3	2	2	0	10	9	0	3	3	1	32	19	2	15
2 cm.	B	5	1	6	6	0	6	1	4	7	6	3	3	6	0	6	0	3	9	12	5	19	12	6	18
	S	3	0	9	0	3	9	0	5	7	5	4	3	0	0	12	1	2	9	3	5	28	6	9	21
4 cm.	B	9	0	3	11	0	1	0	0	12	6	0	6	3	3	6	7	0	5	12	3	21	24	0	12
	S	3	1	8	9	0	3	0	1	11	5	1	6	3	2	7	12	0	0	6	4	26	26	1	9
Total	B	14	4	18	22	3	11	1	4	31	18	7	11	12	4	20	17	3	16	27	12	69	57	13	38
	S	6	1	29	12	3	21	1	6	29	17	8	11	5	2	29	22	2	12	12	10	86	51	12	45

TABLE XL—RESULTS OF ALL FOUR SUBJECTS TOGETHER

Divergence		Horiz			Vert		
		R		L	U		L
1 cm.	B	45	46	53	49	45	50
	S	21	84	39	27	87	30
2 cm.	B	42	58	44	21	37	86
	S	21	87	36	9	89	46
4 cm.	B	42	48	54	44	12	88
	S	30	79	35	27	80	37
Total	B	129	152	151	114	94	224
	S	72	250	110	63	256	113

Third Apparatus, sixth series. (Control V). Eccentric Fixation (Indirect Vision). Three divergences were used, three colors, one aperture (2 cm.).

In the first line of the table the headings, "Above," "Right," "Below," "Left," indicate the position of the fixation light with reference to the object lights.

TABLE XLI—Individual Results—Subject F.

Divergence		Y: Fixation— Above Horiz R = L	Y: Right Vert U = L	Y: Below Horiz R = L	Y: Left Vert U = L	G: Above Horiz R = L	G: Right Vert U = L	G: Below Horiz R = L	G: Left Vert U = L
1 cm.	B	0 10 2	0 12 0	0 11 1	6 6 0	0 8 4	6 2 4	0 7 5	7 5 0
						Impos 12	Impos 12	Impos 12	Impos 12
	S	0 9 3	0 12 0	0 12 0	5 7 0				
2 cm.	B	4 5 3	6 3 3	0 6 6	12 0 0	5 4 3	2 4 6	0 0 12	3 7 2
		Impos 5	Impos 5	Impos 8	Impos 6	Impos 7	Impos 7	Impos 4	Impos 6
	S	0 4 3	3 4 0	0 4 0	0 6 0	0 2 3	2 2 1	0 5 3	0 6 0
4 cm.	B	7 2 3	6 3 3	0 4 8	12 0 0	2 4 6	1 5 6	0 2 10	11 1 0
						Impos 2	Impos 4		
	S	3 6 3	0 12 0	0 12 0	0 12 0	0 4 6	0 8 0	0 12 0	0 12 0
Total	B	11 17 8	12 18 6	0 21 15	30 6 0	7 16 13	9 11 16	0 9 27	21 13 2
		Impos 5	Impos 5	Impos 8	Impos 6	Impos 21	Impos 23	Impos 16	Impos 18
	S	3 19 9	3 28 0	0 28 0	5 25 0	0 6 9	2 10 1	0 17 3	0 18 0

Divergence		R: Above Horiz R = L	R: Right Vert U = L	R: Below Horiz R = L	R: Left Vert U = L	Total: Above Horiz R = L	Total: Right Vert U = L	Total: Below Horiz R = L	Total: Left Vert U = L
1 cm.	B	3 3 6	3 7 2	0 2 10	5 7 0	3 21 12	9 21 6	0 20 16	18 18 0
		Impos 12	Impos 12	Impos 12	Impos 12	Impos 24	Impos 24	Impos 24	Impos 24
	S					0 9 3	0 12 0	0 12 0	5 7 0
2 cm.	B	1 2 9	4 5 3	0 1 11	6 5 1	10 11 15	12 12 12	0 7 29	21 12 3
						Impos 12	Impos 12	Impos 12	Impos 12
	S	0 9 3	4 6 2	0 5 7	7 5 0	0 15 9	9 12 3	0 14 10	7 17 0
4 cm.	B	2 7 3	5 1 6	3 0 9	7 2 3	2 25 9	12 15 9	3 18 15	18 15 3
		Impos 4	Impos 2	Impos 3	Impos 3	Impos 6	Impos 6	Impos 3	Impos 3
	S	3 5 0	0 10 0	0 7 2	0 9 0	6 15 9	0 30 0	0 31 2	0 33 0
Total	B	6 12 18	12 13 11	3 3 30	18 14 4	15 57 36	33 48 27	3 45 60	57 45 6
		Impos 16	Impos 14	Impos 15	Impos 15	Impos 42	Impos 42	Impos 30	Impos 39

TABLE XLII—INDIVIDUAL RESULTS—SUBJECT H.

Divergence		Y												G											
	Fixation—	Above Horiz			Right Vert			Below Horiz			Left Vert			Above Horiz			Right Vert			Below Horiz			Left Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
1 cm.	B	2	10	0	7	5	0	4	8	0	0	7	5	12	0	0	6	6	0	2	10	0	5	7	0
	S	No judgments of size. Impos												No judgments of size. Impos											
2 cm.	B	5	7	0	12	0	0	9	3	0	5	5	2	0	11	1	1	11	0	8	4	0	6	0	6
	S	No judgments of size. Impos												No judgments of size. Impos											
4 cm.	B	0	8	4	7	5	0	6	5	1	0	12	0	0	8	4	7	4	1	6	6	0	8	4	0
	S	No judgments of size. Impos												No judgments of size. Impos											
Total	B	7	25	4	26	10	0	19	16	1	5	24	7	12	19	5	14	21	1	16	20	0	19	11	6
	S																								
		R												Total											
1 cm.	B	0	9	3	3	3	6	6	6	0	5	7	0	14	19	3	16	14	6	12	24	0	10	21	5
	S	No judgments of size. Impos																							
2 cm.	B	5	2	5	0	12	0	9	0	3	4	6	2	10	20	6	13	23	0	26	7	3	15	11	10
	S	No judgments of size. Impos																							
4 cm.	B	11	1	0	6	6	0	6	4	2	1	4	7	11	17	8	20	15	1	18	15	3	9	20	7
	S	No judgments of size. Impos																							
Total	B	16	12	8	9	21	6	21	10	5	10	17	9	35	56	17	49	52	7	56	46	6	34	52	22
	S																								

TABLE XLIII—INDIVIDUAL RESULTS—SUBJECT C.

Divergence		Y												G											
	Fixation—	Above Horiz			Right Vert			Below Horiz			Left Vert			Above Horiz			Right Vert			Below Horiz			Left Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
1 cm.	B	3	7	2	0	9	3	4	8	0	0	6	6	0	11	1	0	10	2	2	10	0	0	12	0
	S	Lights judged equal in size in every case.																							
2 cm.	B	9	1	2	0	5	7	6	6	0	0	4	8	1	11	0	3	7	2	6	6	0	3	2	7
	S	Lights judged equal in size in every case.																							
4 cm.	B	6	6	0	6	6	0	1	2	9	3	5	4	8	4	0	3	8	1	5	7	0	0	2	10
	S	Lights judged equal in size in every case.																							
Total	B	18	14	4	6	20	10	11	16	9	3	15	18	9	26	1	6	25	5	13	23	0	3	16	17
	S																								
		R												Total											
1 cm.	B	0	11	1	0	5	7	9	3	0	0	6	6	3	29	4	0	23	13	12	22	2	0	24	12
	S																								
2 cm.	B	5	4	3	0	7	5	3	9	0	0	1	11	15	16	5	3	19	14	15	21	0	3	7	26
	S																								
4 cm.	B	1	8	3	6	0	6	6	6	0	3	7	2	15	18	3	15	14	7	12	15	9	6	14	16
	S																								
Total	B	6	23	7	6	12	18	18	18	0	3	14	19	33	63	12	18	56	34	39	58	11	9	45	54

TABLE XLIV—Individual Results—Subject P.

Diver-gence		Y: Fixation— Above Horiz R	=	L	Right Vert U	=	L	Below Horiz R	=	L	Left Vert U	=	L	G: Above Horiz R	=	L	Right Vert U	=	L	Below Horiz R	=	L	Left Vert U	=	L
1 cm.	B	0	5	7	0	12	0	0	1	11	3	3	6	0	1	11	0	10	2	0	2	10	0	0	12
	S	No judgments of size. Impos												No judgments of size. Impos											
2 cm.	B	3	9	0	3	4	5	0	0	12	6	6	0	0	3	9	0	5	7	0	0	12	4	0	8
	S	No judgments of size. Impos												No judgments of size. Impos											
4 cm.	B	0	1	11	4	2	6	0	0	12	5	4	3	0	1	11	5	7	0	0	3	9	10	0	2
	S	No judgments of size. Impos												No judgments of size. Impos											
Total	B	3	15	18	7	18	11	0	1	35	14	13	9	0	5	31	5	22	9	0	5	31	14	0	22
	S																								
		R												Total											
1 cm.	B	0	2	10	0	2	10	0	3	9	7	2	3	0	8	28	0	24	12	0	6	30	10	5	21
	S	No judgments of size. Impos																							
2 cm.	B	0	4	8	1	5	6	0	0	12	5	0	7	3	16	17	4	14	18	0	0	36	15	6	15
	S	No judgments of size. Impos																							
4 cm.	B	0	0	12	2	10	0	0	1	11	8	0	4	0	2	34	11	19	6	0	4	32	23	4	9
	S	No judgments of size. Impos																							
Total	B	0	6	30	3	17	16	0	4	32	20	2	14	3	26	79	15	57	36	0	10	98	48	15	45
	S																								

TABLE XLV—Results of all Four Subjects Together

Divergence	Fixat'n.	All colors together: Above Horiz R	=	L	Right Vert U	=	L	Below Horiz R	=	L	Left Vert U	=	L
1 cm.	B	20	77	47	25	82	37	24	68	38	38	68	38
	S	Impos		96	Impos		96	Impos		96	Impos		96
		0	45	3	0	48	0	0	48	0	5	43	0
2 cm.	B	38	63	43	32	68	44	41	35	68	54	36	54
	S	Impos		84	Impos		84	Impos		84	Impos		84
		0	51	9	9	48	3	0	50	10	7	53	0
4 cm.	B	28	62	54	58	63	23	33	52	59	56	53	35
	S	Impos		78	Impos		78	Impos		75	Impos		75
		6	51	9	0	66	0	0	67	2	0	69	0
Total	B	86	202	144	115	213	104	98	159	175	148	157	127
	S	Impos		114	Impos		114	Impos		111	Impos		111
		6	147	21	9	162	3	0	165	12	12	165	0

with third apparatus and those used with the second apparatus. Three colors, one aperture (2 cm.)

TABLE XLVI—INDIVIDUAL RESULTS—SUBJECT F.

Divergence		Y						G						R						Total					
		Horiz			Vert			Horiz			Vert			Horiz			Vert			Horiz			Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
8 cm.	B	5	4	3	8	0	4	1	2	9	0	3	9	4	3	5	1	3	8	9	9	18	10	6	20
	S	0	6	6	0	10	2	6	6	0	0	8	4	9	2	1	0	12	0	15	14	7	0	30	6
13 cm.	B	10	2	0	0	3	9	6	3	3	0	4	8	5	1	6	9	0	3	21	6	9	9	7	20
	S	0	12	0	0	12	0	0	12	0	0	12	0	6	6	0	2	10	0	6	30	0	2	34	0
18 cm.	B	3	7	2	3	9	0	0	11	1	3	3	6	10	0	2	1	5	6	13	17	6	7	18	11
	S	7	5	0	0	9	3	8	4	0	0	12	0	10	2	0	0	9	3	25	11	0	0	30	6
24 cm.	B	2	9	1	0	10	2	4	6	2	0	12	0	5	7	0	0	9	3	11	22	3	0	31	5
	S	2	7	3	0	12	0	0	12	0	0	7	5	4	5	3	0	12	0	6	24	6	0	31	5

TABLE XLVII—INDIVIDUAL RESULTS—SUBJECT H.

Divergence		Y						G						R						Total					
		Horiz			Vert			Horiz			Vert			Horiz			Vert			Horiz			Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
8 cm.	B	4	5	3	0	0	12	3	5	4	4	3	5	3	7	2	4	4	4	10	17	9	8	7	21
	S	1	11	0	2	0	10	1	9	2	0	12	0	0	12	0	0	12	0	2	32	2	2	24	10
13 cm.	B	2	10	0	8	3	1	2	10	0	0	4	8	6	0	6	0	4	8	10	20	6	8	11	17
	S	0	12	0	2	10	0	0	12	0	0	10	2	4	2	6	0	11	1	4	26	6	2	31	3
18 cm.	B	3	5	4	6	6	0	4	4	4	2	6	4	0	6	6	2	6	4	7	15	14	10	18	8
	S	2	10	0	0	12	0	3	9	0	0	12	0	0	12	0	0	12	0	5	31	0	0	36	0
24 cm.	B	0	12	0	0	12	0	0	12	0	1	8	3	0	11	1	2	7	3	0	35	1	3	27	6
	S	0	12	0	0	12	0	0	12	0	1	11	0	0	11	1	2	10	0	0	35	1	3	33	0

TABLE XLVIII—INDIVIDUAL RESULTS—SUBJECT C.

Divergence		Y						G						R						Total					
		Horiz			Vert			Horiz			Vert			Horiz			Vert			Horiz			Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
8 cm.	B	8	0	4	6	1	5	7	3	2	5	0	7	3	0	9	0	2	10	18	3	15	11	3	22
	S	0	12	0	0	11	1	0	12	0	0	11	1	0	12	0	0	11	1	0	36	0	0	33	3
13 cm.	B	9	0	3	0	7	5	12	0	0	0	5	7	5	7	0	1	3	8	26	7	3	1	15	20
	S	0	12	0	0	12	0	0	12	0	0	12	0	0	12	0	0	12	0	0	36	0	0	36	0
18 cm.	B	6	6	0	9	3	0	8	4	0	0	9	3	10	2	0	3	7	2	24	12	0	12	19	5
	S	1	11	0	3	9	0	2	10	0	0	10	2	7	5	0	0	12	0	10	26	0	3	31	2
24 cm.	B	0	6	6	2	7	3	8	3	1	0	12	0	6	6	0	3	7	2	14	15	7	5	26	5
	S	0	12	0	0	12	0	0	12	0	0	11	1	0	12	0	0	11	1	0	36	0	0	34	2

TABLE XLIX—INDIVIDUAL RESULTS—SUBJECT P.

Divergence		Y						G						R						Total					
		Horiz			Vert			Horiz			Vert			Horiz			Vert			Horiz			Vert		
		R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L	R	=	L	U	=	L
8 cm.	B	5	0	7	12	0	0	0	3	9	5	0	7	0	6	6	5	3	4	5	9	22	22	3	11
	S	2	1	9	2	3	7	0	3	9	5	2	5	1	5	6	7	1	4	3	9	24	14	6	16
13 cm.	B	6	0	6	8	0	4	0	0	12	2	0	10	3	1	8	8	0	4	9	1	26	18	0	18
	S	3	0	9	6	3	3	0	3	9	0	8	4	3	1	8	6	1	5	6	4	26	12	12	12
18 cm.	B	6	0	6	12	0	0	3	1	8	6	2	4	6	0	6	12	0	0	15	1	20	30	2	4
	S	1	6	5	2	7	3	4	3	5	5	5	2	1	1	10	8	0	4	6	10	20	15	12	9
24 cm.	B	0	8	4	6	0	6	0	4	8	12	0	0	0	6	6	7	5	0	0	18	18	25	5	6
	S	0	8	4	0	9	3	0	8	4	8	4	0	0	9	3	4	5	3	0	25	11	12	18	6

TABLE L—Results of all Four Subjects Together

Divergence		All colors together Horiz R	=	L	Vert U	=	L
8 cm.	B	42	38	64	51	19	74
	S	20	19	33	16	93	35
13 cm.	B	66	34	44	36	33	75
	S	16	96	32	16	113	15
18 cm.	B	59	45	40	59	57	28
	S	46	78	20	18	109	17
24 cm.	B	25	90	29	33	89	22
	S	6	120	18	15	116	13

TABLE LI—THIRD APPARATUS, EIGHTH SERIES (CONTROL VII). QUANTITATIVE EVALUATION OF THE PHENOMENON. THREE COLORS WERE USED, 1 DIVERGENCE (2 CM.), 1 APERTURE (2 CM.)

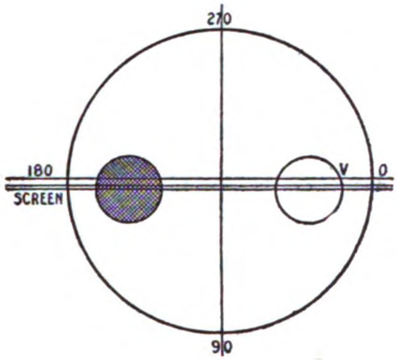
Fernald—	Yellow	Green	Red
1 Screen	2 errors Judged = in 0 Lower judged brighter in 270	2 errors Lower judged brighter in 270 twice	2 errors Lower judged brighter in 270 twice
2 Screens	All correct	All correct	All correct
Chamberlain— 1 Screen	2 errors Right judged brighter in 180 Upper judged brighter in 90	4 errors Judged = in 180 twice Judged = in 270 Lower judged brighter in 270	2 errors Judged = in 180 Lower judged brighter in 270
2 Screens	1 error Judged = in 180	1 error Judged = in 270	2 errors Left judged brighter in 0 Lower judged brighter in 270
3 Screens	All correct	All correct	All correct
Perrin— 1 Screen	3 errors Left judged brighter in 0 Right judged brighter in 180 Lower judged brighter in 270	2 errors Lower judged brighter in 270 Judged = in 0	2 errors Left judged brighter in 0 Upper judged brighter in 90
2 Screens	All correct	All correct	All correct
Hayes— 1 Screen	2 errors Judged = in 180 Lower judged brighter in 270	2 errors Lower judged brighter in 270 twice	2 errors Judged = in 180 Lower judged brighter in 270

DIAGRAM OF LIGHTS AS USED IN
SERIES EIGHT (TABLE LI)

Right brighter	in		0	position
ower	"	"	90	"
eft	"	"	180	"
pper	"	"	270	"

The disk, as represented, is set in ie 0 position with the screen behind ie left hand light. The positions the lights, referred to in discuson of tables, corresponds to the potion of the aperture marked V. hen this is at 90 the lights are in e 90 position, etc.

The standard light (unscreened) as of 2 candle power intensity, as easured by the photometer. This as the same as the intensity of the andard light (placed at the 60 cm. vision on the tracks) in the second paratus.



CONCLUSION

The phenomenon in question is evidently not a general or con stant characteristic of all judgments on luminous points or areas It apparently occurs under relatively definite conditions. First it occurs most clearly, and perhaps exclusively, when the light are so placed that they may be simultaneously fixated in direc vision (using "direct vision" as synonymous with "occurrenc of the retinal image on the fovea"). Second, the effect is pre dominantly, if not indeed exclusively, concerned with the bright ness factor in these experiments. Third, it cannot, in any con clusive way, be correlated with normal right- or left-handedness Fourth, the appearance of the phenomenon itself cannot, in othe than a very indirect manner, be correlated with practice in mak ing these judgments, although such practice apparently does as sist in making the phenomenon more evident. Fifth, the phe nomenon must apparently be classified strictly as an illusio rather than as an effect dependent on known structural or func tional variations in different areas of the retina. These fiv points will be considered in order.

First. The sizes of the total retinal images, *i.e.* the distance between the outside edges of the images, of the pairs of ligh used throughout these experiments are as follows:

	Aperture	Divergence	Total distance between oustide edges of two lights	Retinal ima
1—	1 cm.	0	2 cm.	41.2μ
2—	2 cm.	0	4 cm.	82.4μ
3—	4 cm.	0	8 cm.	164.8μ
4—	1 cm.	½x	2.5 cm.	51.5μ
5—	2 cm.	½x	5 cm.	103.0μ
6—	4 cm.	½x	10 cm.	206.0μ
7—	1 cm.	=	3 cm.	61.8μ
8—	2 cm.	=	6 cm.	123.6μ
9—	4 cm.	=	12 cm.	247.2μ

	Aperture	Divergence	Total distance between outside edges of two lights	Retinal image
-	1 cm.	2x	4 cm.	82.4μ
-	2 cm.	2x	8 cm.	164.8μ
-	4 cm.	2x	16 cm.	329.6μ
-	1 cm.	13 cm.	15 cm.	309.0μ
-	2 cm.	13 cm.	17 cm.	350.0μ
-	4 cm.	13 cm.	21 cm.	432.6μ
-	2 cm.	18 cm.	22 cm.	453.2μ
-	2 cm.	24 cm.	28 cm.	576.8μ
-	13 mm.	30 cm.	32.6 cm.	671.6μ
-	13 mm.	50 cm.	52.6 cm.	1083.6μ
-	13 mm.	1 M.	102.6 cm.	2113.6μ

Taking the above figures for the retinal distance between the tside edges of the various pairs of images and assuming .4 mm. the diameter of the fovea, it is apparent that 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13 and 14, in the above summary of the retinal eas affected, are all foveal, while 15 is likewise foveal if we cept the larger measurements often given for the fovea: *e.g.*, itsch's measurements, from edge to edge of the depression, en as .5 to .75 mm. 19 and 20, the large divergences used on second form of apparatus, are clearly extra-foveal, *i.e.* when image of one light is on the fovea the other must in all cases l outside the fovea. 16 and 17, the largest divergences ed in the seventh series (control VI) with the third form of paratus, and 18, the smallest divergence used with the second rm of apparatus, are doubtful. The question of whether or t they may be foveal depends on the estimate of the size of fovea which we accept. Fritsch's figures (above) would ke all three possibly foveal, while Rivers' estimate (Schafer's ysiology) of .2 mm. to .4 mm "or larger" would make them probably extra-foveal. Taking .5 mm. as the diameter of the d-free area and .8 mm. as the diameter of the area in which cones predominate (Koster's measurements), 17, 18, 19 and would extend beyond the rod-free area but only 19 and 20 beand the area in which the cones predominate. It is difficult to tain a definite statement of the extent of the area lacking in

rhodopsin. If we accept the statement frequently made, *e.g.* Schafer and Symington in Quain's Anatomy, Cunningham Rivers in Schafer's Physiology, etc., that it is lacking through out the macula lutea we are still in doubt as the actual area i question, as the diameter of the macula is variously given b different authors from .5 mm. to 6 mm. or even larger. (Cun ningham, 2 mm. to 3 mm.; Howell, 6 mm.; Dimmer, .5 mm. Schafer and Symington, 2 mm.; Foster, longest diameter of th oval macula 2 mm.) The smallest of these figures would mak the four largest divergences used (1 m., 50 cm., 30 cm., and 2 cm.) extra-macular. The largest estimate of the yellow spo would make the judgments, even on the 1 m. divergence clearl macular; would, in fact, allow of very considerably eye movemer without the image of either light falling outside the macula. As suming the measurement most frequently given for the macula 2 mm., only the largest divergence, 1 m., would make the image clearly extra-macular. In the eccentric fixation judgments wit both the second and third form of apparatus (in which th phenomenon failed to appear) the retinal images of the tw lights were clearly extra-foveal. In the judgments with th second form of apparatus in which a central fixation point wa used, midway between the two lights, the distance between th outside edges of the retinal images was 671.6 μ so that bot images could not simultaneously appear on the fovea; and, i those cases where the image of the fixation point fell insid the central half of the foveal area, neither of the object light stimulated the fovea. In the judgments with the third form o apparatus, in which a fixation point was used at the side or abov the object lights, the images were always extra-foveal. In thos cases in which the image of the fixation point fell on the cent of the fovea the images of the object lights occurred 402 μ fro the edge of the fovea; even when the image of the fixation poin fell on the edge of the fovea farthest from the images of th object lights these latter were 210 μ from the near edge o the fovea. In the judgments with the second form o apparatus where fixation points were placed outside the circl

n which the object lights revolved, the images of these latter vere still more peripheral, the fixation light being located farther rom the line joining the object lights than it was with the third orm of apparatus.

In the case of the judgments with the third form of apparatus, abulated and described as "permanent fixation judgments," Tables 36-40) where a fixation light was placed between the bject lights, the images were all foveal—except in the possible ases of the occurrence of the image of the fixation light on the xtreme edge of the fovea, in which cases one image might, of ourse, be extra-foveal. The phenomenon, though reduced in imortance, was perfectly apparent in these judgments, occurring in quite regular manner for three of the subjects—though reersed for the fourth.

In only one other of the control series did either or both of ne images occur outside the fovea. In the series with "varied ivergences" (Tables 46-50) the two cases in which the lights vere separated by 18 cm. and 24 cm. respectively produced nages which were necessarily extra-foveal—one or both, deending on the fixation. In both these cases the phenomenon ailed to appear. With the 13 cm. divergence, both in this conrol series and in the main series with this apparatus, the image f one light might readily become extra-foveal as the result of naccuracy in the fixation of the other; and in the judgments vith this divergence the phenomenon was greatly reduced and ot infrequently absent.

The one fact of importance which appears clearly from these neasurements and comparisons is that *the phenomenon in queson occurs where the distance between the lights is such that ney may be simultaneously seen in foveal vision, and that it fails appear where the distance between the lights is such that they annot be seen in this way.* That, in the former case, the two nages are actually present, simultaneously, on the fovea in very judgment, is, of course, wholly improbable. The known ature of fixation of luminous points in relative darkness would reclude such a supposition. The smaller the distance between

the lights, however, the greater will be the possible eye movement which does not cause either image to occur outside the fovea. It is with these smaller divergences (½ the diameter of one light, equal to the diameter and twice the diameter) that the phenomenon appears most clearly. The failure of the phenomenon to appear as clearly with the o divergence is apparently explicable on other grounds, *i.e.* the tendency of the lights to fuse when placed in this position. The phenomenon appears, therefore, to be rather definitely and exclusively concerned with foveal vision. Its occurrence in this area accords with the apparently foveal character of the astronomical observations in which the effect was first noticed. Its exclusive restriction to this area was by no means necessarily implied in the nature of those observations, nor was there any evident reason for supposing that it would be so restricted. In coming to the conclusion, however, that it is limited in it's occurrence to strictly foveal vision we have only succeeded in defining it's retinal scope and a physiological explanation of its occurrence in this area is still to be sought. At present no known structural or functional difference between the upper and lower halves of the fovea has been found to cover the facts. The suggested explanation, based on the brightness difference of the stimulation of the upper and lower halves of the retina in ordinary vision, particularly in out-door vision, is wholly inadequate to cover the facts. It would be natural to assume, on this explanation, that the effect would occur as clearly —if not, in fact, more strikingly—in peripheral judgments, where one image was above and the other below the fovea, as in exclusively foveal estimates of brightness. The inadequacy of this explanation, as a physiological account of the facts, is especially apparent in connection with the absence of any known correlative disparity, of a structural nature, between the lower and upper halves of the fovea.

Second. The effect seems to be predominantly, if not, indeed, exclusively, concerned with the brightness factor. Throughout the series of experiments in which the phenomenon has appeared clearly it has uniformly been more evident in the brightness than

the size judgments. In those judgments in which the lights ve been reported as unequal in one attribute, equal in the other, : inequality has almost exclusively concerned itself with the ghtness factor. The total number of cases in which the judg- nts were the same for brightness and size forms an overwhelm- ; majority of all the judgments, while those in which the two es of judgment favored opposite lights were so infrequent as be almost negligible for all but one subject. The introspective :ounts of the different subjects from an important element in r conclusion that the phenomenon is predominantly concerned th the brightness judgments. There was a uniformly greater tainty of the actual objective inequality of the lights in the ghtness factor than in the size factor. This was typically ex- essed by one subject's comment, several times repeated, that ie lights you show me are more frequently unequal in bright- ss than in size. I quite often have the feeling that one light :ually *is* brighter than the other but only *seems* larger and is lly equal to the other in size." Similarly, from another sub- t, "I wonder whether those lights really are different in size only seem so"—this latter comment coupled with a complete surance of the brightness *inequality* of the lights in a *majority* the judgments. Every one of the subjects was decidedly sur- ised at being told, at the conclusion of the experiments, that, th the exception of the seventh control series, the lights had vays been equal in brightness with the third apparatus. The ne information in regard to the relative size of the lights used very little astonishment. This limitation of the phenome- n to the brightness judgments and the reference of such pref- ence as was shown in the size judgments to a tendency of these follow the brightness judgments explains, in large part, the ilure—or, rather, the reversal—of the familiar "figure 8-letter illusion" in the judgments on size. It might, perhaps, be more rrect to say that the natural tendency toward this illusion with jects of this type prevented the phenomenon from appearing as ikingly in the size as in the brightness judgments. Which- er way we regard it, it seems rather clear that in this set of

experiments the effect *was* predominantly concerned with the
brightness judgments, and it is at least a possible interpretatior
that it was exclusively so concerned.

The results of experiments on size discrimination in periphera
vision and in peripheral versus foveal vision, *e.g.*, H. C. Stevens
results, are evidently not relevant to this experiment. The sam
applies to the experimental investigations of size discriminatio
which concern themselves, wholly or in part, with foveal judg
ments. The evident dependence of the size judgments, in th
present experiments, on the brightness factor, as well as the com
plete reversal of the typical foveal size illusion, offer sufficien
reason for excluding these size judgments from consideration i
the present case. The relation of such illusions as are represente
in the figures of Zöllner, Poggendorf, Müller-Lyer, Wundt, Her
ring, Loeb, etc., will be considered under the fifth head.

Third. Evidently no correlation can be made between the char
acter of the vertical judgments and normal right or left handed
ness. One might, however, naturally look here for some explana
tion of the less noticeable preference for one of the lights in th
horizontal position. Nevertheless, the results fail to show an
such connection even in the horizontal judgments. Of the fiv
subjects used with the third form of apparatus, one showed
slight preference for the right-hand light, another a decide
preference for the left throughout both the main set of exper
ments and the control series. The third subject, (A), who acte
only through the main set, showed a decided preference for th
left throughout his judgments and the fourth subject, (C), who
results are limited to the control series, favored the right han
light more frequently. The remaining subject manifested a co
sistent, though slight, preference for the right in the main serie
a more decided choice of the left in the control experiment
Yet all of these subjects were normally right handed. This la
of correlation between the horizontal preference and norm
right-handedness is, of course, less noteworthy, when we co
sider the exclusively foveal nature of the judgments in questio
in connection with the probable nature of the cortical represent

tion of the two foveæ. The characteristic horizontal preference of each subject failed, moreover, to be reversed when the left eye was used instead of the right. This was equally true when binocular vision was substituted for the monocular vision used in most of the experiments.

Fourth. The fact that continued practice in making this type of judgment does not tend to make the phenomenon disappear is, of course, clearly shown in the results. The two subjects with whom it appeared most consistently and in the most striking manner were the ones—and the only ones—who had served throughout the experiments with all three forms of apparatus. The subject, on the other hand, for whom the effect was probably least striking and was complicated by the greatest number of horizontal preferences, as well as actual reversals of the vertical preference, served only in the experiments with the third form of apparatus. The extent to which practice made the phenomenon more apparent is difficult to determine. The experiments with the first two forms of apparatus, in which subjects H. and F. gained a large amount of experience with this form of judgment, practically failed to show the phenomenon at all. They started on the experiments with the third form of apparatus with a large amount of experience in making judgments on the size and brightness of luminous areas. The situation was, however, decidedly different in the two previous series, with the first and second form of apparatus; different in the former case chiefly in regard to the subject's attitude and the character of the lights, in the latter case because of the much greater separation of the lights and the consequent difference in the retinal area stimulated. To what extent this could properly be called practice, with reference to the last series, is very doubtful, and particularly so when it is remembered that the phenomenon failed to appear in the earlier series. During the progress of this last series of experiments there was no striking increase or diminution in the importance which the phenomenon played in the total number of judgments. Any effect which practice may have had is, evidently, only indirectly apparent in the results. It appears chiefly, if at all, in the more or less consistent and unambiguous

occurrence of the phenomenon with subjects who had, respec
ively, gained a larger or smaller amount of experience in makin
this type of judgment. It is not evident in any decided an
constant increase in the importance of the phenomenon durin
any one series of experiments nor during the entire group
experiments made with one form of apparatus. The fact of i
marked appearance with subjects trained in making these judg
ments accords with the conditions under which it occurs in a
tronomical observation.

Fifth. The results of control series one with the third form
apparatus suggest the possibility—even the probability—that th
explanation of the phenomenon is not to be found in any *know*
structural or functional peculiarities of different areas of th
retina, or, more strictly, of the fovea. If, as both the resul
and the introspective reports on this series strongly indicate, th
mental attitude of the subject was a determining factor in the
judgments, *i.e.* if merely thinking of the lights as in the hor
zontal-vertical positions, though they remained in the obliqu
positions relative to the subject's eye, caused the phenomeno
to appear in quite the regular way, then there seems every reaso
to suppose that the phenomenon in question is much more close
related to an illusion than to differences in the perceptions
identical stimuli dependent on functional or structural diffe
ences in the retina. Neither the results of the experiments n
the introspective accounts of the different subjects suggest an
satisfactory explanation of the illusion; nor does the literatu
concerning the various illusions of brightness and size thro
any light on the problem. Such explanations of the variou
forms of illusion as depend *directly* on erroneous judgments
the relative size of different areas are evidently irrelevant
the present discussion, as indicated above. This applies as we
to such explanations of the Poggendorf, Zöllner, Müller-Lye
Loeb types of illusion as to explanations of the figure 8-
letter S type of illusion and the well known misjudgment
vertical versus horizontal lines. It seems equally impossible
correlate the type of explanation frequently given for the hor

zontal-vertical line illusion, *i.e.* the relative ease of eye movement in the two planes, with the present illusion of brightness. It has been suggested, as an explanation of certain horizontal-vertical illusions, that the order in which the objects are fixated has an important, if not a determining, influence on the preference shown. In order to form some evaluation of the importance of this factor the subject was asked to state, in three groups of experiments with the third form of apparatus, the order in which the lights were fixated. Their reports showed that in a majority of cases the light first looked at was the one judged to be brighter. (The size factor is here left out of consideration. Where a size preference was shown it followed, as we have seen, very closely with the brightness preference.) This correlation was by no means uniformly true and the cases in which the lower light was looked at first did not account for all of the cases in which the lower light was judged brighter. Moreover, in a large number of cases the final judgment was made, not after a single look at each of the two lights but after several alternate fixations of the two areas. It is impossible to determine just what proportion of the judgments was made in this way but, on the basis of the introspective reports of the different subjects, it is certain that a considerable proportion was so made—quite possibly a majority. It is difficult to see, therefore, how priority of fixation could have been a determining influence in the appearance of the phenomenon. In the case of prolonged, successive fixation of two relatively intense lights, priority of fixation might possibly be a more important factor, *i.e.* through the effects of fatigue. It is evidently far-fetched, as an explanation, in view of the conditions of these experiments. In order to still further settle this point the control series with a permanent central fixation was made. The subject was requested to hold the fixation of the central point as steadily as possible, before, during and after the exposure of the object lights; in fact, from the time the shutter in front of the eyepiece was raised till it was lowered. Reports of any failure to do this were especially requested. All those judgments in which this report was given were thrown out.

Admittedly a considerable amount of variation in the fixation was possible, unknown to the subject. It is hardly possible, however, that this alteration in fixation could, in the entire ignorance of the subject, have entered into the judgments to such an extent as to form a controlling influence in the results. The subjects were perfectly conscious of the difference in procedure when they fixated, as steadily as possible, the center of one of the lights and when, on the contrary, they allowed their eyes to move "over the surface of the light." Yet the diameter of one light was, with the largest of the three divergences used, only half the distance between the inner edges of the two lights and one third the distance between their centers. In these judgments with a permanent central fixation the phenomenon, as previously stated, appeared with complete clearness, though not, to be sure, as markedly as in the main series. Even this diminution of the phenomenon might be explained in terms of practice, as the length of this control series was not sufficiently great for the subjects to gain a familiarity with this procedure equivalent to that which they had acquired for the main series.

Our final conclusion is, therefore, that in this phenomenon we are confronted with a horizontal-vertical illusion of brightness concerned predominantly with foveal vision. Its occurrence in these experiments corresponds quite exactly with the conditions of astronomical observation, in connection with which it was first brought to our notice. That it is an illusion, strictly, is indicated by the fact that it depends, in part at least, on the mental attitude of the subject. That it is restricted largely, if not exclusively to foveal vision indicates its dependence on functional and hence on structural, peculiarities of this region as contrasted with the rest of the retina. It is impossible, at the present time, to indicate or describe this characteristic of the fovea. It appears equally impossible to offer an adequate explanation of the illusion by analogy with the various types of illusion described and, in part, explained in the literature. The present account can lay claim, therefore, to descriptive value only and can make no pretence of being an adequate explanatory treatment of the facts in question.

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Recognition: A Logical and Experimental Study

By

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oblem.

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I. HISTORICAL RÉSUMÉ OF THEORIES OF PERCEPTION

There is no sphere of psychology where greater diversity of opinion is manifest than in the discussions concerning the phenomenon of recognition. Not only have a large number of radically different explanatory theories been advanced, but experimental research has led to few universally accepted conclusions. The present monograph represents an attempt to clear up some of the existing confusion on the basis of logical analysis and of experimental data. Before proceeding to this part of the work, however, we shall survey briefly the main theories of recognition as they have been propounded and point out how they have been affected by the results of laboratory investigations. Inasmuch as recognition takes place not only in the perceptual but also in the ideational sphere, the discussion will be divided into two corresponding sections. This is necessitated by the fact that, up to the present time, practically all psychologists have considered these two problems as distinct, and have accorded each a separate treatment.

(1) Theories of Perceptual Recognition

We find that we can divide these theories into three groups.* First some authors regard recognition as a function of a peculiarity of content that is sui-generis—*viz.*: an unique feeling of familiarity, only encountered where judgments of oldness are affirmed (or at least are possible). Secondly, other writers agree with those just mentioned in regarding recognition as a function of a peculiarity of content, but do not regard this content as a feeling of familiarity but as some specific variation in the prop-

*In classifying writers, expositions given without qualification are assumed to be regarded by the writers as universally valid. It has to be taken for granted that if a writer means a description only to apply to some and not to all instances, he has indicated this qualification explicitly in some fashion or other.

erties or mode of behavior of processes which would be functio ing in a different way if recognition did not take place, *e.g.*, t reproduction of images or the movement of the attention ov a field of interest. Writers of the third school differ from those previously mentioned in that they reject the conception a content basis for the cognitive classification of material as o or as new. Recognition is in its essence a consciousness of re erence, a meaning, an awareness of relationships between t present and the past, which is not dependent on or due to t appearance of a feeling of familiarity or any other like phase the extant situation. The consciousness of reference is unme iated, is sufficient unto itself. It will be more convenient to d cuss the second group first.

a. Recognition as a Function of Peculiarities of Content Oth Than a Feeling of Familiarity.

1. *Revived Image or Impression.* One of the earliest theori that we find, the one in fact that in spite of occasional oppositi maintained itself until 1889 as the predominant doctrine, stat that the recognition of a percept is due to the revival of form impressions of the object or of its image. Although, of cour these two classes of psychological phenomena are sharply d tinguished today, yet as long as the realistic and associatio schools held sway, the two were not differentiated, at least with any clearness. We can then treat theories dealing w them as identical in intent unless a distinction is explicitly ma There are two different ways in which this revived content m be regarded as functioning. Either the new percept and t resurrected presentation are distinct and recognition is explain as the result of the conscious comparison of the two, or the ima or impression is assimilated to, or fused with, the percept such a fashion that it never enjoys an independent existence a its presence is only indicated to the introspecting subject by t fact that recognition has taken place.

The earliest representative of this view that I have co across is Ampère,[1] who says that recognition takes place as

[1] *Essai sur la Philosophie des Sciences*, 1834.

consequence of the fusion of a percept and its image. Bain, the leader of the associationalist school, and Spencer who had much in common with this general point of view, also maintained practically the same doctrine. Says Bain[2] "In the perfect identity between a present and a past impression, the past is recovered and fused with the present instantaneously and surely. So quick and unfaltering is the process that we lose sight of it altogether." Where the identity is not perfect, it is a chance whether the new stimulus will be identified, as it may not reproduce the old impression. Spencer's[3] doctrine is very similar. "Thus, the fundamental law of the association of relations, like the fundamental law of the association of feelings, is that each at the moment of presentation aggregates with its like in past experience. The act of recognition and the act of association are two aspects of the same act." Volkmann,[4] representing the Herbartian school, states that recognition is the result of the calling out of a reproduced idea by a presented object. If the two are totally alike, they fuse, and the whole process is dissolved in a feeling of 'Förderung', best translated perhaps as "mutual reinforcement." When the identity is not perfect, the fusion apparently does not take place, but as a result of the difference there is a simultaneous stimulation and repression of the reproduced by the reproducing content, and a consequent series of fluctuations in the latter.

We find the same theory appearing among men of a different outlook. Munk,[5] the physiologist, thinks of recognition as the result of a conscious comparison of the percept and its image. Here for the first time, the reproduced content is regarded as being something distinct from the new impression. The words fusion, assimilation, Verschmeltzung (Volkmann) indicated that the image or revived impression is generally blended with the percept. In fact, its presence is only indicated to the subject by the act of recognition itself. But in the case now before us the reproduced content is itself within the sphere of observable pro-

[2] *Senses and Intellect*, 3rd edition, 1868, p. 460.
[3] *Principles of Psychology*, 1892, I, p. 269.
[4] *Lehrbuch der Psychologie*, 1884, I, p. 414.
[5] Quoted by Külpe, *Psychology*, 1895, p. 171.

cesses and a conscious comparison is possible. The same assumption is found in other early experimentalists. Wolfe,[6] using the recognition method for testing the memory of tones, assumed on purely logical grounds that conscious comparison between the sensation and its image takes place. Höffding[7] is the most consistent and careful formulator of this theory that we have. He says that all recognition rests on a connection (Verbindung) between a stimulus and the corresponding image. In many cases the latter does not enjoy an independent existence, *i.e.,* cannot be introspectively isolated. This is the condition met with where we have the so-called unmediated recognition. The only thing that distinguishes the represented content from a novel one is the presence of a simple unanalyzable quality, the Bekanntheitsqualität. In seeking the basis of this we can represent the process from a psychological point of view by a formula. Let A represent the present stimulus, and a an image, surviving from an earlier experience. Then the formula for recognition would be $\left[\frac{A}{a}\right]$, the brackets indicating that fusion takes place. The two aspects A and a are only logically isolable and the statement in its ultimate analysis means that the result of the earlier presentation of A which leads to recognition is the same as that which under other conditions renders a *bona fide* reproduction of a possible. This would occur, for instance, when some stimulus B arouses the image a as a result of association by contiguity. In addition to these cases of unmediated recognition, Höffding admits that there are instances where the reaction is to be explained in the manner set forth by Lehmann (see below), and calls the phenomenon successive recognition.

These doctrines all see in association by similarity the basis of the revival of the image by the percept. In 1889, however we find Lehmann[8] coming forward in defense of a theory founded on association by contiguity. The view current at the time among those who considered the latter a law of secondary rank was that, as a new impression A had never been experienced

[6] *Phil. Stud.* III, 1886, p. 534.
[7] *Vierteljhrsch. f. Wissen. Phil.,* XIII, 1889, p. 420.
[8] *Phil. Stud.* V, 1889, p. 96.

in company with any of the images that were supposed to accrue to it as a result of association by contiguity, it was only by the rearousal of *a* that the process could be conceived as taking place. *A* would call out *a* through the force of similarity and then *b, c, d,* etc., images of contiguous associates of *a,* would put in an appearance. In answering this, Lehmann says, "Da eine Vorstellung *A* und eine reproducirte Vorstellung *a* ganz derselbe Zustand ist und in demselben moment nur durch verschiedene Ursachen hervorgerufen, so ist es durchaus unverständlich wie der eine dieser Zustände eine Wirkung, die Reproduction von *b,* sollte hervorrufen können, welche der andere nicht hervorbringen könnte." Not only is the supposedly necessary intervention of the image *a* a fiction, but the doctrine is not even called for as a working hypothesis to render intelligible certain processes such as the recognitive reaction. The latter can easily be understood as due to the working of the principle of contiguity. We must, says Lehmann, distinguish between sensations incapable of further analysis and perceptions which are complex and which are the result of a gradual upbuilding in time, in other words, are not sensed as a whole simultaneously. In the case of the latter, the phenomenon of recognition is explained as follows. I experience the sensation *A* which is part of a more complex object in the process of being perceived, and this as a result of association by contiguity arouses anticipatory images, *b, c, d,* etc. If then, in the further experience of the object I encounter the sensations *B, C, D,* etc., corresponding to these images, recognition takes place. If the object is frequently encountered, one such identification is sufficient.

It must be understood that we are not ordinarily conscious of these so-called Congruenzschätzungen, by which the identity of the image and the object is established. In fact we seem here to be practically in the presence of Höffding's doctrine of unmediated recognition, the only difference being that a different law of association is regarded as the operative cause of the reaction. The whole doctrine so far elaborated is an explanation

of "simple" recognition, that is, the cases where there is no consciousness of the circumstances under which the previous experiencing of the known content took place. On the other hand, when this last is present, we have Wiedererkennen mit Umständen. This involves, besides the reproduction of the images whose identification with the repeated elements of content gives the essence of the reaction, the revival of details representing the conditions obtaining at the time of the earlier experience. We have then the complete formula.

$$\begin{array}{rcccccl} A+B+\ldots\ldots & f & + & g & + & h & \\ & | & & | & & | & \\ & F & + & G & + & H & +m+n \\ & \multicolumn{5}{c}{\text{Recognition}} & \text{Umständen} \end{array}$$

In cases where percepts are recognized but the process of anticipation by an image and its subsequent justification by the actual experience of the corresponding sensation cannot be introspectively observed, *i.e.,* where we encounter what Höffding calls unmediated recognition which does not involve any isolable image or other associates, Lehmann posits the occurrence of the whole action in the region of the subconscious. This seems to carry us but little beyond Höffding. Still there is one great advantage in the general form of statement here presented, in that the process is capable of being, on occasion, introspectively observed. This gives us, then, something more than a purely hypothetical mode of explanation.

In the case of simple sensations, *i.e.,* of impressions which on account of their simplicity do not admit of a process of successive anticipations and verifications during the apprehension of their content, Lehmann advances two modes of explanation. In the first place it may be due to a comparison between a sensation and a memory image of it that has been aroused in anticipation, *i.e.,* before and not subsequent to the presentation of the repeated stimulus. Secondly, where this is not possible, the calling out of a name by association is sufficient to lead to the classification of the stimulus as known. In this latter case, however, we do not have a true recognition, as no comparison takes place, a

process which, as has been shown, is always involved. Lehmann denies the occurrence of the unmediated recognitive reaction with sensations.

Although the work in which it occurs has been superceded by his later books, we may cite Baldwin's statements in his "Senses and Intellect" as an illustration of the predominant tendency of the time which we are considering. He says, "In the case of the second perception of an object, its recognition is accomplished by means of an image which is already recognized. We institute a comparison between the percept and the image, and pronounce them the same or similar."[9] Sully also adds himself to the long list of professors of the faith. Although he seems to recognize in one place that there is much truth in Lehmann's strictures against a naïve realism which regards sensations as continuing to exist after they have ceased to be experienced and of being capable of being revived, he cannot forego the temptation to fall into the same error. "The simplest form of assimilation is to be found in that process by which a present sensation is reapprehended or recognized as familiar. . . . Such assimilation is automatic or "unconscious" in the sense that there is no separate and distinct recalling of a past sensation, and clear awareness of the relation of the present sensation to its predecessor. . . . What takes place is the calling up by a present sensation of the trace or residuum of a past sensation . . . , which trace merges in or coalesces with the new sensation, being discernible only through the aspect of familiarity which it imparts to the sensation."[10] Jodl[11] also enunciates practically the same doctrine. He speaks about the Zusammenschmelzen of a perception with one of the same content reproduced by it, as being the basis of recognition. On occasion, the process may take place in such a way as to be introspectively observable. This is true where there is some difficulty involved in the reaction.

Watt's[12] recently promulgated doctrine of integration of at-

[9] *L. C.*, 2nd edition, pp. 172-3.
[10] *The Human Mind*, I, 1892, p. 181.
[11] *Lehrbuch der Psychologie*, II, 2nd ed., 1903, p. 129.
[12] *Brit. J. of Psych.*, IV, 1911, p. 127.

tributes is clearly related to theories of this type. The main difference is that it is not the percept and the image in their entirety that fuse but one of their attributes. Watt wants to build up a causal science of psychology, which shall not need to appeal to any principles of explanation and combination outside of its own field. Complex experiences of a peculiar indescribable type, evident only after direct acquaintance which are called secondary modifications of experience, are to be viewed as resulting from the integration and linking together of sensations due to fusion of attributes in respect to which the sensations differ. Recognition is regarded as such a secondary modification of experience, due to the integration of the differing attributes of order of experiences which are in recurrence. It is exceedingly hard for me to understand exactly what Watt actually means by the attribute of order in this connection. It seems to be an attribute of sensations whereby they are distinguished even when possessed of the same quality, intensity and extensity. The basis for the distinction lies in an inherent aspect of arrangement, whereby the order of every sensation is fixed relatively to all others present. Where recognition is concerned, the term refers, I should judge, to position in a temporal series. This explanation of recognition as due to the integration of the order attributes of experience logically implies that the earlier one should be revived. To account for the alleged cases in which no such revival can be indicated, Watt suggests that an integration is possible when the remaining qualities and other attributes are very much in the background. It may require a lengthy search to reveal the presence of the qualities, extensities, etc. whose order is being integrated. Experiment has shown that the orders of objects may be present and admitted introspectively without the qualities being distinctly observable. Attributes are, therefore, capable of more or less separation in their appearance in consciousness. The probability of this explanation would be even greater where, as in recognition, the attention is concerned primarily with the attribute of order alone. "We may maintain then that recognition is based upon the psychological integration

of the order aspects of percepts although it is often present before associated percepts can be identified introspectively." Still eventual reproduction is implied.

The employment of experimental methods has given us evidence concerning the validity of the doctrine that recognition is to be explained as due to a comparison with a revived image or impression. We have already mentioned the work of Wolfe which is of interest largely on account of its pioneer character. The method was purely objective (no introspective evidence was sought for) and the work therefore contributes nothing more than a mere assumption. Lehmann, also, in his first work[13] argues from the results of experiments in which no careful introspective evidence is accumulated. The purpose underlying his researches was to bring forward proof of his own theory as opposed to any doctrine which would explain recognition as due to the calling out of an image by the corresponding percept as a result of the working of the law of association by similarity. Using the method of recognition in a series of tests with gray disks, he found that the smaller the difference between the stimuli among which the standard had to be recognized, the greater was the number of erroneous judgments. The same result is procured by an increase in the number of different stimuli employed. Lehmann assumes that in these cases a memory image is carried over from the initial presentation, and that the accepting or rejecting of the second stimulus is the result of a direct comparison. This assumption is of course compatible with the results mentioned. He found in addition that the individual variations in correctness of judgment were directly correlated with the general ability to remember either concrete data of sense on the one hand, or abstractions on the other. A subject with a memory especially adapted to retaining material of the former type was found to make more correct judgments than a subject with a mathematical bent. This result would also naturally be expected provided recognition takes place as assumed. In addition, it was found that the standard stimulus which is presented much more frequently in the course of an experiment than

[13] *Phil. Stud.*, V, 1889, p. 96.

any of the variants was not more likely to be the subject of correct judgment when re-presented than were any of the latt Rather in the case of one subject the percentage of correct jud ments was the same for all stimuli in the test trials, and the otl estimated the variants more correctly. This Lehmann claim is in accord with his own hypothesis, as the strengthening of anticipatory memory image ought to work to reduce errors all directions, while if we assume that recognition is the res of the fusion of the images of former impressions (called subsequent to the presentation of the stimulus) with the n content the result should be different. Under these conditi the represented standard should find waiting to receive it a c stantly increasing number of images, which should increase percentage of correct judgments in its case, while the varia should receive no assistance from the circumstance. This, th is the first evidence that we find brought forward in favor of a theory which would explain recognition as the result of a c scious comparison between an *anticipatory* image and an obj The technique, however, is not well adapted to bring out actual subjective processes involved, inasmuch as no introspect evidence is sought for.

In 1895, Bourdon[14] working with series of words in wh one individual was repeated, found that recognition often occ red without representation intervening. Bentley[15] also brin forward evidence to the same effect. He employed gray di and used the methods of recognition, of continuous change, a of right and wrong cases. His general conclusion, based on trospective reports of his subjects, was that recognition of takes place without a comparison with a memory image. T does not mean that this may not occur, especially where the s ject is of a strongly visual type. Still when no active reprod tion was possible, where no vestige of an image survived the terval, the subjects could decide quickly and with confiden F. Angell,[16] working with tones, used various distractions.

[14] *Rev. Phil.*, 40, 1895, p. 153.

[15] *Am. J. of Psych.*, XI, 1899-1900, p. 1.

[16] *Am. J. of Psych.*, XI and XII, 1899-1900, p. 67, and 1900-1901, p. 58.

trospective evidence played but little part in his conclusions, which were that the majority of the judgments in his experiments did not involve a comparison with an image. As has been said, however, we have here again an argument based in the main on objective methods of experimentation. Whipple[17] gives us an exhaustive introspective analysis of the processes involved in the recognition of tones. He concludes that the presence of the auditory image is not necessary to the judgments of either equality or difference. On the other hand, a comparison actually does take place in certain cases.

Abramowski and Katzaroff also present evidence that images are not necessary for the recognitive reaction. One piece of work by the former[18] contains introspective evidence, and is hence of value. The second paper,[19] being of a purely objective character, gives us but little insight into the actual processes involved. Katzaroff,[20] who used geometric designs as stimuli, is concerned with the introspective evidence of his subjects. He concludes that while images may be present in some cases of recognition, their appearance constitutes a second period in the total reaction, the immediate conscious phenomenon being a feeling of familiarity which is the ultimate basis for the acceptance of the stimulus. He finds among other interesting things, that even when images are present recognition may not take place, and that, in other instances, the presence of contradictory images is not sufficient to mediate a judgment of newness. These facts in themselves are, of course, strong evidence that any attempt to explain the recognitive reaction as the result of the *mere* appearance of an image and a judgment of novelty as the result of the *mere* absence of an image must end in failure. For we find that the concomitant variation is not in any way thoroughgoing. Meumann[21] also reports judgments where images are not concerned, at least as far as the subject can determine on introspective

[17] *Am. J. of Psych.*, XII, 1900-1901, p. 409, and XIII, 1902, p. 219.
[18] *Arch. de Psych.*, IX, 1910, p. 1.
[19] *Journal de Psych.*, VII, 1910, p. 301.
[20] *Arch. de Psych.*, XI, 1911, p. 1.
[21] *Arch. f. die Ges. Psych.*, XX, 1911, p. 36.

grounds. The same conclusion is also indicated by Moore,[22] wl employed a very interesting technique. He presented to his su jects series of groups of figures in which one figure was alwa repeated. The subject was not required to be able to report wh figure was repeated, but only that such repetition had taken plac Introspection concerning the processes involved was then call for. Moore found that the subject might be aware that *so* figure was being repeated, although he had little or no knowled concerning its form. Strong,[23] while insisting on the necessi of some kind of mediating content, reports many instances which images were not observed.

This, then, completes the list of the important experimer which have brought forward evidence in regard to the tenabili of the hypothesis that recognition is invariably a function revived images. The evidence seems overwhelmingly conclusi that these latter, while they may on occasion serve to media judgments of oldness are by no means necessary for the appea ance of the latter. Furthermore, Katzaroff has clearly shov that if images are to be considered as occasional criteria for t judgments of old, some additional differentiating mark must established which characterizes images capable of mediati recognition as opposed to those correlated with judgments novelty. It should, of course, be noted that none of this evider can directly refute a doctrine which bases its faith on fus images. The latter are absolutely insusceptible of introspect isolation, and are of a purely hypothetical and explanatory ch acter. Inasmuch then as they cannot be observed, they are f the experimentalist non-existent; and we may relegate them or and for all to the sphere of useless incumbrances. It is far b ter to say that on occasion (provided of course no other crite are present) recognition consists in a mere consciousness of r erence in which case the theories would belong to our third gro than to drag in a labored hypothesis that smacks strongly of naïve realistic and atomistic preconceptions.

2. *Recognition as a Function of the Appearance of Associat*

[22] *Atti di V Congr. Intern. di Psych. in Roma*, p. 286.
[23] *Psych. Rev.*, XX, 1913, 33, p. 1.

—In contradistinction to the type of theory we have just been discussing, the general teachings of the writers who belong to this second school is that recognition is due, not to the revival of the image or impression of the recognized object itself, but to the appearance of associated ideas or images (of other objects). This also is a doctrine of great age. We find Wolff[24] in the middle of the eighteenth century proclaiming the essence of it. His teaching may be summarized in the assertion that the revival of images and ideas representing a former experience, of which the present percept was a part, is the basis of the recognition of the latter. Novelty would, presumably, be due to the absence of all such associates. Lehmann,[25] also, although his main theory is one calling for the revival of images of the object itself, has one supplementary hypothesis which naturally falls under this class. The recognition of simple sensations under conditions which forbid the anticipatory arousal of an image is regarded as due to the ability to classify or label, which he calls Wiedererkennen durch Bestimmung. This latter is a case of association by contiguity.

Exner's teaching cannot be classified as belonging to any of our set types, but claims rather a number of affiliations. One of the main agencies in mediating the reference of a present experience to a previous similar one is the Auftreten von Nebenerregungen in the cortex, which, in so far as it is accompanied by consciousness, is to be interpreted as the Auftreten of associated Empfindungen. A complete understanding of Exner's theory involves the conception of the Bahnung. Just as one excitation in the central nervous system can hinder or prevent entirely the "running off" of another excitation, so the contrary condition may be realized, and this Ablauf may be assisted. This is due to the clearing (frei machen) by the action of another current of the tracts to be traversed. This phenomenon of facilitation is called Bahnung.[26] Turning the attention to either a sensory impression, a movement, or a memory image renders the paths concerned especially responsive to incoming

[24] *Psychologia Empirica,* Sec. 174, 1738.
[25] *Phil. Stud.,* VII, 1892, p. 169.
[26] *Entw. Zu e. phys. Erklärung der Psych. Erscheinungen,* 1894, p. 76 ff.

currents while the conducting ability of other areas is de creased.[27] Furthermore, there is no confusion owing to the in ability to distinguish between an increased state of excitatio due to this Bahnung through the act of attention, and one du to an increased intensity of the stimulus.[28] The subject know what the occasion for the change is. Applying the doctrine t the recognitive reaction, we find in the first place that the repet tion of a stimulus increases the intensity of the excitation of th tracts concerned without a corresponding increase in the ol jective intensity of the stimulus. Also, the recognitive con sciousness is distinguished by the presence of images associate with the actual sensations as a result of having been experience together with them on some previous occasion. That there a no objective grounds for the appearance of these images, *i.* that they are not functions of a stimulus, is known to the su ject, one might almost say, immediately. For he is aware th there is no corresponding arousal of the sub-cortical tracts, condition which would exist in case the content were traceab to stimulation from without.[29]

Stout and James also are well-known exponents of this ge eral line of argument. Stout says that as a result of the recu rence of a like impression in a dissimilar context, both it and corresponding disposition are modified. This is due to the pre ence of reproductive tendencies which owe their origin to se sations and percepts that have been experienced at some form time as companions of the recognized content. Though the may not be strong enough to cause the revival of the correspon ing previous impression, they give rise to an increased comple ity in the represented sensations.[30] James makes a distincti between memory and recognition proper. "And to refer a special fact to the past epoch is to think that fact with the nam and events which characterizes its dates, to think it, in sho with a lot of contiguous associates."[31] This is memory prop

[27] *Entw. Zu e. phys. Erklärung der Psych. Erscheinungen*, 1894, p. 16 ff.
[28] *Ibid.*, p. 168.
[29] *Ibid.* p. 241.
[30] *Analytic Psych.*, II, 1896, pp. 10-11.
[31] *Psychology*, I, 1905, p. 650.

When, however, a phenomenon is met with often, in great varieties of contexts, this setting of associates fails to come up. Rather the latter form too confused a cloud. All that we have is a sense that there are associates, a doctrine which approaches very closely the theories which posit unmediated meanings. With complex phenomena, the different elements may be regarded as being mutually associated by contiguity. If then the object is encountered for the second time, an "intrinsic play of mutual associations among the parts would give a character of ease to familiar percepts which would make of them a distinct subjective class."[32] This, then, is the phenomenon of recognition as distinguished from explicit memory.

Two varieties of this general type of theory are of sufficient importance to warrant special notice. Ribot[33] and James[34] believe that among the contiguous associates are always ideas of the date or time when the previous contact with the recognized content occurred. As has been pointed out, however, the latter author would assert this only in the case of memory proper. James,[35] James Mill,[36] and Claparède[37] all declare that recognition involves a consciousness of self. To recognize is to refer the object to a previous experience which I myself have had, to realize that I am in the presence of a bit of content which has been incorporated into a previous moment of my existence.

Betz's[38] theory of the Einstellung also belongs here. As opposed to Vorstellung which denotes the elements of content which are contributed as a result of stimulation from without, he used the word Einstellung to denote the reaction to the stimulus on the part of the subject. These reactions include the arousal of pleasure-pain components, bodily changes as a direct result of the stimulation, the establishment of apperceptive and emotional relations. Wherever, as a result of past experience,

[32] *L. C., I.*, p. 674.
[33] *Diseases of Memory*, 1893, p. 46 ff.
[34] *L. C., I.*, p. 650.
[35] *L. C.*
[36] *Analysis of the Phen. of the Human Mind*, Vol. I, 2nd ed., 1878, p. 328.
[37] *Arch. de Psych.*, XI, 1911, p. 79.
[38] *Arch. f. die Ges. Psychologie*, XVII, 1910, p. 266.

a stimulus arouses in me certain reactions of the kind described for which no justification can be discovered in the present natur of the content itself, and which must therefore be regarded a a carried-over Einstellung, recognition will take place. Bet observed several cases in his own experience that tended to justif the hypothesis. Encountering a man on the street who wa vaguely familiar, Betz found that there was a slight tendenc to smile set up. Nothing about the existing situation could b conceived as being the adequate cause of the reaction. Late on, Betz remembered an amusing incident in a street car i which the man had figured conspicuously. The re-instatemer of the Einstellung unjustified by present conditions had bee the cause for the appearance of the past reference.

The experimental evidence concerning these doctrines is fa from unanimous. Lehmann,[39] in the work already cited, bring forward proof that the recognition of simple sensations, in case where the arousal of an anticipatory image cannot be posite must be due to the ability to name. He employed three seri of gray disks, in one of which there were five individuals, th outer limits being black and white, and the three intervenin grays being separated from the extremes and from each oth by equal steps. In a second series there were six disks, an in a third nine. The disks of a series were presented in th order of brightness to the subject, and then, later, one by or at random, and he was asked to give the place in which each ha appeared at first. If we assume with Lehmann that there are i general five descriptive names that we are capable of using i distinguishing the members of a series of shades of gray, and naming is a means of recognizing, we should expect to find th the series containing five members would be the locus of th greatest number of correct judgments, and the series of nine o the fewest. This was borne out by the results obtained. In th series of nine, the percentage of correct estimates was reduce to a number that practically corresponded to that representin chance.

[39] *Phil. Stud.*, V, 1889, p. 96.

In a later series[40] of experiments on the recognition of smells, Lehmann found that in nearly all cases the appearance of associated ideas marked those experiences that were classified as known. Of especial importance were the reproductions of names. Lehmann divided associations into those that were wrong, *i.e.*, could never have been accompaniments of previous experiences of the recognized smell, and those that were right, *i.e.*, were true reproductions. He found that in the great majority of instances where the content was classed as new, no correct reproductions were present while the reverse was true where recognition took place. Where the stimulus was recognized and no reproduced content was observable, Lehmann fell back on the field of the subconscious. When the associates remain below the threshold we have practically the immediate recognition of Höffding.

Bentley[41] also appears to bring forward evidence to the same effect. He says that the appearance of stimuli calling forth the same verbal description as the standard was the signal for a recognitive reaction. In fact, the presence of some kind of mediating associates, such as generic images, or verbal connotations, or ideas of persons, etc., seems in general, though not always, to have been the rule with his subjects where judgments of old were returned. Gamble and Calkins,[42] on the other hand, who undertook to test Lehmann's work, report decidedly different results. These authors found that (1) unknown stimuli are accompanied by associated ideas; (2) recognition occurred when there were no associates, at least none clear enough to be observable; (3) where the order was noted, the associates generally appeared after the decision. In another series of experiments[43] with visual and olfactory stimuli, the authors found reason for questioning Lehmann's conclusions concerning the value of naming in mediating recognition. Evidence tending towards the same conclusion is cited by Abramowski,[44] who found that the

[40] *Phil. Stud.*, VII, 1892, p. 169.
[41] *L. C.*
[42] *Zeit. f. Phys. und Psych.*, XXXII, 1903, p. 177.
[43] *Zeit., etc.*, XXXIII, 1903, p. 161.
[44] *L. C.*

work of thought in analysing and naming is not necessary fo judgments of identity. Katzaroff,[45] although he observes tha on occasion, associations carried over from the earlier experienc are regarded by the subject as being indicative of the previou presence of the stimulus, nevertheless believes that a feeling c familiarity is an act which precedes every other psychic act an hence that associations even when they are present, are, after al but secondary phenomena. He brings forward in support of h contentions the fact that for his subjects at least, many recog nitions take place where no content except a feeling of famil arity could be isolated, that, on occasion, the presence of specif memory of details may fail to lead to a judgment of oldnes and that, since memories of an explicit character are attache only to certain details, they cannot be regarded as mediating recognition of the whole.

In Meumann[46] and Strong[47] we again find evidence that a sociations are generally characteristic of old content and lack c them of new. Meumann says that with a new stimulus there a suspension of the flow of ideas and images. The unknown not the center for the arousal of a series of reproductions, as the known. It is very difficult during the early stages of lear ing, however, to discover the presence of even obscure repr ductions, and there are cases where there seems to be absolute no structuralistic basis for the judgment returned. We see to be here concerned with an immediate reference to the pas Meumann, however, believes that in these instances it is probab that there are certain obscure criteria present, especially Forma gefühle and organic sensations. Thus, though it is not true th recognition always involves associates, on the whole Me mann seems to show that they are habitually in evidence. Tl same may be said of Strong. Strong does not limit the assoc ates to mere ideas, but speaks also of emotions, motor respons etc. Nevertheless, he is explicit in stating that recognition seen to depend on the fact that the same mental process that accon

[45] *L. C.*
[46] *L. C.*
[47] *L. C.*

panied the stimulus at the time of its initial presentation is revived.

We see then that all experimenters report cases of recognition where associations are present, and also others where they are lacking. The number of the latter is relatively small, however, except in the work of Abramowski and Katzaroff. The main point of disagreement is as to how they are to be interpreted. Lehmann would bring in associative activity in the sphere of the subconscious. Gamble and Calkins would admit them as valid exceptions to any general statement of the rôle of associates in recognition. Katzaroff would read them out of court altogether in so far as they claim to be unique and would posit an antecedent and ultimate feeling of familiarity as always present. The evidence presented by Gamble and Calkins that unrecognized content may arouse associates, and by Katzaroff that the presence of specific memories will not invariably lead to judgments of old, tends to show that the mere appearance of the latter cannot furnish a basis of differentiating old and new, at least not with all subjects.

3. *Homophonie.*—Semon[48] has propounded a theory based on his doctrine of the mneme. When like stimuli are applied simultaneously to corresponding points of a sensitive area, the resulting sensations are rendered more vivid. Whatever differences may exist between them are thrown into relatively sharp relief. This reciprocal influence is known by the term Homophonie. When we have a simultaneous excitation of a sensation and its mnemic trace or engram, the same phenomenon is operative and we experience a keen consciousness of the difference in the time order of the original excitations concerned. The two processes, the sensation and the mnemical impression, do not fuse, but rather there is a real relation of co-existence in time. This peculiar case of Homophonie is recorded in consciousness as the recognitive reaction which in its essence consists of a reference to the past. Occasionally we have comparison with a memory image.

[48] *Die Mneme,* 1908; *Die Mnemische Empfindungen,* 1909, pp. 313, 334, 382.

4. *Habit.*—Bergson[49] has lately developed a theory based, it would seem, on what we may call physiological recognition. A man who uses a hammer to drive nails, and a tennis racket to play with certainly does not recognize in the true sense of the word; and yet just in so far as the peculiarly appropriate reactions are set up we have something which in its essence is related to recognition. Bergson seems to have taken his cue from reactions of this type. The basis of recognition, in his estimation, is to be sought in the consciousness of a well-regulated motor reaction to a stimulus. At first our movements in the presence of an unfamiliar object are uncertain. When we become too accustomed to dealing with it, perception is useless, the reaction being purely automatic. There is, however, an intermediate stage where the object is still consciously perceived, and where at the same time a high degree of automaticity of the responding movements has been perfected. It is the consciousness of this well-regulated motor reaction that lies at the basis of our classifying the stimulus as known. This is instantaneous recognition, of which the body is capable by itself. In the majority of cases, however, there are, in addition, memory images which go out to meet the incoming impression.

For Baldwin assimilation is at the bottom of recognition.[50] And "in assimilation we have the general statement of all the forms, nets, modes of grouping which old elements of mental content come to bring to impose upon the new." In turn "this assimilation is due to the tendency of a new sensory process to be drawn off into preformed motor reactions." One form of motor discharge due to a stimulus is a more or less consolidated motor reaction fixed by natural selection, and this is what we ordinarily call attention. In the case of a re-presented content, the peculiar movements that are concerned in attending to that specific object are more easily executed. This surely is evidence of the working of the principle of habit. Moreover a train of associated images is reinstated.

5. *Feeling of Ease.*—Finally some authors attribute recogni-

[49] *Matter and Memory*, 1912, p. 109.
[50] *Mental Development*, 3rd ed., 1906, p. 292 ff.

tion to the sense of ease which attends the subsequent running off of a nervous process as contrasted with its first arousal. The recurring currents are traversing paths which have been opened up and worn, so to speak, and in accordance with the law of habit they encounter less resistance in their course. The whole process is facilitated. Corresponding to this increased automaticity on the physiological side, we have a feeling of ease in connection with the processes involved in perception on the psychological side. This, in turn, serves as a clue for the classification of the stimulus as known. (In some cases the latter aspect is all that is mentioned, the physiological relations receiving no notice.) The earliest representative of the doctrine that I know of is Charles Bonnet.[51] Later writers are Maudsley,[52] Höffding,[53] Exner,[54] and, in a way, Theodor Lipps.[55] In the case of the latter the physiological substratum is not mentioned. The theory of the "Bahnung" is central in Exner's statement. A tract is "gebahnt" through the action of currents running over it, *i.e.*, the next excitation will so to speak find its way prepared for it. As a result, the same stimulus will, without any assistance from the attentive processes, cause a more intense excitation of the tracts concerned and this will in turn be registered in consciousness as ease of entrance into the focus. As was shown before, the source of this increased intensity will not be attributed to any added intensity of the stimulus itself. The doctrine of Lipps involves his conception of Energie. He speaks of the Verschmeltzung of the Vorstellung with the Empfindung, but goes on to specify that what he actually means by this is that the Empfindung appears with a higher degree of energy, and energy means assertiveness in consciousness, the tendency to force an appearance in the focus, regardless of the like tendency of other content. In addition, repetition allows the attention to move from one part of a content to the other with less hindrance. A

[51] *Essai de Psych.* 1775, Ch. V.
[52] *The Phys. of Mind,* 1889, p. 513.
[53] *L. C.*
[54] *L. C.* p. 240.
[55] *Grundtatsachen des Seelenlebens,* 1883, p. 229 ff.; 189 ff.

novel detail causes the attention to be held up, the sweep ov
a series of habitual relations being impeded. It should be not
that Lipps does not explicitly state that these factors lie at t
basis of recognition, but we may, I believe, assume from t
general discussion that this would be his teaching.

These doctrines have some experimental evidence which m
be cited in their favor. Bourdon, in the work already mentione
says that a known object is more rapidly, more profoundly a
more easily perceived than is an unknown one. Meumann al
says that in apperceiving a new content we encounter an expe
ence of interruption and of starting which partakes somewh
of the character of a slight feeling of fright. When the a
pearance of a new syllable is unexpected, the phenomenon
noticeably tied up with lack of overt motor activity, the inn
vation of antagonistic muscle groups and a stiff, upright postu
of the body being involved. The speech movements may be te
porarily impeded, resulting in a delay in the expression of t
judgment. There is also a suspension of the flow of ideas a
images, the new stimulus not fitting right in as a link in the ch
but rather breaking in on the process. In contrast to this
find that the pattern of consciousness initiated by the appearar
of known syllables is always characterized by an easy runni
off of the psychological processes. Perception as such is easi
as is also the articulation of the syllables. Again the stimu
fits right into the series of ideas and constitutes a center for t
arousal of associations.

b. *Recognition as a Function of a Feeling of Familiarity:*

Theories of this type all posit the appearance of a unique fe
ing as the basic element in recognition. By feeling we und
stand either an ultimate unanalyzable form of consciousn
which is different from sensation or image, or a complex of su
processes and of certain sensations, usually organic, in the sen
indicated by Titchener. The latter point of view would not
take it, deny the uniqueness and individuality of any particu
type of complex. A certain combination of the two necess
elements, as in the case of the feeling of familiarity, for

stance is a combination thoroughly peculiar and isolable. Again the feeling of familiarity may be the result of other factors, but these are never in themselves sufficient to complete the recognitive reaction. The peculiar tonus is necessary if recognition is to take place.

We find among the defenders of this theory many of the most famous psychologists of modern times. Wundt[56] speaks of a Wiedererkennungsgefühl, and attributes its appearance to the assimilation of the recognized content by imaginal elements surviving from former experiences. When we have only encountered the object once before, the assimilation is brought about by the elements dating from the single earlier presentation. As in all cases of assimilation proper, we are unable to observe the reproduced constituents in the total complex. If the object has been met with many times, all of the past impressions will contribute to the quota of reproduced content which is active in the assimilation, but the degree of participation in the process will vary. Sometimes it may even happen that there will be a temporal succession in the order in which the imaginal constituents put in an appearance. The elements that are first aroused may, then, be relatively subordinate and unusual attributes (Merkmale) of the object in question and may merely serve as introductory to the more important elements which carry out the assimilation. This latter phenomenon is indicated in consciousness by the appearance of the feeling of familiarity. Under the conditions just described, we are accustomed to say that we have mediate recognition, as the earliest reproduced content merely serves to usher in that responsible for the assimilation. In these cases we pass into the sphere of successive association, *i.e.*, the mediating images may be observed as independent contents of consciousness. It should be remembered, however, that the process always ends with an assimilation proper. One great variety of mediating content is composed of complications, that is, images which belong to a different sphere of sensation from that through which the stimulus is received.

[56] *Grundzüge der Phys. Psych.* III, 1903, 5th ed. pp. 535 ff.

Külpe[57] also, it appears to me, should be counted among those who are adherents of this doctrine concerning the feeling of familiarity, although at first sight this may seem a rather arbitrary classification. According to him recognition is of two kinds, direct and indirect. In the former there occurs merely a judgment expressive of familiarity, no reproduction of the sensations involved in previous experiences being occasioned; in the latter, such a reinstatement of factors repeating certain circumstances of the original situation, does occur. Direct recognition is characterized by the effectiveness of the represented stimulus for central excitation. Various local, temporal and conceptual ideas are aroused. In the case of a novel stimulus, on the other hand, such a network of associations is lacking. Also, there is a difference in mood between the known and the unknown. We find that this second factor is an invariable accompaniment of the recognitive consciousness, while the effectiveness for central excitation is often lacking. The mood appears, then, as the really basic consideration. Indirect recognition may be of two kinds. (1) The case where the environment of the represented object is also recognized. We have here really a series of direct recognitions. Only if the object is recognized because it occurs in a familiar setting, and not on its own account, is the recognition truly indirect. We have here no novel element introduced into the situation. All that is added is an inference from attendant circumstances. (2) The environment may be different, however, and in this case recognition takes place when the previous surroundings are recalled, *i.e.,* sensations representing them or knowledge about them are reproduced.

Titchener[58] also is found among the ranks of those who believe in a feeling of familiarity. He says, "The feeling of familiarity is the essential factor in recognizing. . . . The sensations and ideas of the associative and organic reaction then serve to make the recognition definite; the perception comes to us not merely as familiar, but with the especial familiarity of a named, placed, and dated experience." While these associated ideas are or

[57] *Psychology,* 1895, p. 170 ff.
[58] *Textbook of Psychology,* 1911, p. 407.

may be of assistance in recognizing, still as the reaction may take place when they are absent, they cannot be regarded as essential. The feeling of recognition itself is a feeling in the narrower sense, that is, a mental complex that can be analysed into a connected set of sensations and affective processes. The particular constituents are (1) diffuse organic sensations, (2) a pleasurable affective tone. When a stimulus is often repeated, the feeling of familiarity ceases to be aroused, and all that we find is direct apprehension, where the content is taken for granted.

Peillaube[59] also propounds a doctrine with reference to a feeling of familiarity. He, however, sees the basis of the affective reaction in a phenomenon which is an extension of the Bergsonian hypothesis to meet the requirements of cases where recognition occurs without any observable movements. Peillaube would attribute the presence of the feeling of familiarity to the fact that the repeated stimulus tends to arouse immediately with a relatively great amount of ease, a train of associated images and ideas which are closely knit together so as to give on the psychological level what closely resembles the phenomenon of habit in the physiological. The represented term comes into a field in which it immediately takes up old connections. As a result of this organized network into which the repeated stimulus comes we find a diminishing of the *choc interieur* which accompanies the entrance of a new stimulus into consciousness, and that is especially exemplified in surprise. As a result we have the "sentiment" of familiarity.

We have considerable experimental evidence on this matter. Bourdon concludes without a very careful analysis of the assumption involved, that recognition is an intellectual feeling, so-called, belonging in the same general class as feelings of doubt, etc. This feeling of familiarity is hard to analyse, as it is very fleeting and intangible. On the other hand, Bentley offers evidence which would tend to deny the necessity of the presence of any peculiar tone. Two of his three subjects failed to discover any mood whatsoever, and one subject never reported any

[59] *Les Images*, 1910.

organic sensations. Bentley regards this as being the result of his technique. Nevertheless, the fact remain recognition took place without the factors in question present. Whipple, however, speaks of the feeling of fami as being the basic consideration. It can be further analys shows in general two patterns. In some cases, we have jective indication in the variable tone itself, such as wh latter is spoken of as being "more graspable, appealing, stronger, lingering along," etc. These terms seem to i the arousal of more or less definite complex sensations standard, the revival of which by the variable leads to ide tion, and reminds one of Külpe's effectiveness for centr citation. In the second place there may be indications fr observer's own body, such as would be illustrated by the p "a glow of warmth," "a felt sense of ownership." Still W found instances where none of these factors were prese word content "known" or its equivalent being practically was involved in the reaction. The general evidence, the of his work, while favorable to the habitual presence of th ing of familiarity where recognition takes place, does n us to regard it as absolutely essential. Also, Whipple fou pleasantness seems to be the prevailing affective tone i reactions, thus substantiating Titchener's doctrine.

Abramowski concludes as the result of his work, that re tion is the result of the appearance of an *unanalyzable* which wells up immediately on the reappearance of the sti Revival of the image, and the intellectual labor accomp it, is a secondary phenomenon, which is not a conditi recognition, but sometimes accompanies it, and is a s psychic luxury. Katzaroff also believes in the existence ultimate unanalyzable feeling of familiarity, which, as a act, precedes every other reaction in consciousness. E cases where recognition seems exclusively determined by i associations, etc., Katzaroff believes that we must adm there is an antecedent feeling of familiarity which the is unable to isolate introspectively. We have also intros evidence which bears on the doctrine that recognized con

accompanied by peculiar organic complexes which are different from those present with novel stimuli. Bentley found that for one of his subjects, no organic sensations could be introspectively observed. This is of course evidence against the doctrine. On the other hand, we find Gamble and Calkins speaking of a difference in the organic accompaniments involved in the two cases. Meumann also speaks of a peculiar feeling of unpleasantness, coupled with rather definite organic sensations, in the case of unknown stimuli, and of characteristic feelings and "organics" which are qualitatively related to weak feelings of pleasantness and to sensations indicating relaxation, in the case of repeated percepts. Sometimes these were incapable of being introspectively isolated, however. These last experiments together with those of Whipple may be considered as offering proof of the correctness of Titchener's contention that the feeling of familiarity can be analysed into affective processes and organic sensations.

All experimenters, even those who would posit a feeling of familiarity as the ultimate and essential factor in recognition, are forced to admit that there are instances where such a unique content is not introspectively observed. Whipple, Katzaroff, etc., however, believe in its existence even under these conditions, claiming that it escaped the subject, owing perhaps to its weak intensity. This view is, of course, highly speculative. Nevertheless, the experiments are in general favorable to the contention that an ultimate feeling is with most people normally involved when a content is judged old. Another point of disagreement is as to whether the familiarity tone is susceptible of further analysis. Katzaroff, Abramowski and Bourdon do not seem to think that it is, while Whipple is strongly inclined in the opposite direction. Meuman, also, although he does not use the phrase "feeling of familiarity," speaks of what is closely analogous to it from the Titchenerian point of view, when he mentions affective processes and organic sensations. Gamble and Calkins, Meumann, and Whipple all give support to Titchener's doctrine that the latter are habitually concerned in recognition. On the other hand, Bentley seems to offer evidence that with some subjects, at least, such a feeling of familiarity is non-existent.

c. *Recognition as an Ultimate Datum of Consciousness.*

The fact that the mind can refer content to the past is an ultimate fact for the psychologist. The meanings of oldness and of newness are as unanalyzable as is redness or warmth. This does not, however, necessarily signify that there is no peculiarity of content which can be pointed out as the invariable carrier of the reference. In discussing the doctrine of those who see in recognition a unique datum of consciousness, it is extremely difficult to know, in some cases, whether the author is merely insisting on the ultimate character of the cognitive distinction, or is in addition claiming that the latter has no structuralistic basis. In the case of percepts, there is inevitably such a basis in the fact that the recognized stimulus is actually (in the majority of cases) like a former experience, while one judged new is actually altered. For the subject, this similarity does not exist as an immediately observable datum, however, and the defenders of an ultimate consciousness of reference would deny the presence of other isolable criteria. In this connection, it should be understood that we are not regarding relational elements as content though they may rightly be considered to be such.

Going back to a time when the distinction between content and function was not explicitly formulated, we find that for the old faculty psychology, memory was an ultimate faculty of the mind. Reid, Hobbes, and Locke, all were adherents of the same general point of view. In more recent times, the doctrine has been defended by two different groups, a limited number of writers who are not believers in imageless thought, and the members of the Würzburg school and writers who are in sympathy with them and their theories. Among the former we cite Angell, who says, "This fact of recognition . . . seems to be an ultimate and unanalyzable property of consciousness."[60] He then adds that a feeling of familiarity is involved, that recognition is generally pleasant, and that the recognized content is often supplemented by associated images, but continues,[61] "In all cases of

[60] *Psychology*, 4th ed., 1908, p. 225.
[61] *Ibid.*, 228.

conscious recognition, however, it must be remembered that the mental act of explicit recognition is something unique; something which is not simply synonymous with the accompanying conditions which we have been describing." It would appear, then, that Angell is merely insisting on the ultimate character of past reference, a fact which is undeniable. He admits, however, a content basis, a feeling of familiarity. Ebbinghaus,[62] though he does not explicitly name recognition, would, I believe, logically be led to class it with the consciousness of similarity, difference, etc., as one of the "general attributes of sensation." This probably represents a realization of the ultimate character of the meaning side.

Miss Washburn's doctrine,[63] on the other hand, appears to leave no room for any structuralistic difference underlying the cognitive distinction. She says that "recognition is an unanalyzable fact." "That by which the face seen today differs from the face seen for the first time, is something wholly sui generis." This fact has, however, hypothetically a correlate in the fact of central excitation. "By whatever process we imagine one brain center to excite another, the conscious accompaniment of the central excitation is the consciousness of familiarity, of knowness." A sudden sense of having been in a place before, without being able to recall the circumstances, is viewed as the consciousness arising from a process of central excitation, of the passage of a nerve current from one center to another, which is checked before it is completed. In the case of the recognition of percepts, the central excitation which arises so to speak to meet the incoming currents, reinforces the peripheral excitation.

In taking up the theories of the imageless thought exponents and of those who are in more or less sympathy with them, we note Miss Calkins' doctrine of relational elements. As is well known Miss Calkins has long contended for this third group of elements which are just as irreducible bits of conscious content as any of the abstractions of the structuralistic type of analysis. While admitting that organic sensations and a feeling of pleasure

[62] *Grundzüge der Psych.*, I, 2nd ed., 1905, p. 432.
[63] *Phil. Rev.*, 1897, p. 267.

are truly elements in the recognitive reaction, she clai
there are in addition relational elements involved. Thes
include the consciousness of myself as persisting through
ing experience, and of the object as identical with so
past.[64] And these latter are irreducible to anything excep
ing terms, I take it. We hardly need to go into much
regard to the theory of the Würzburg school, as it is well
There have been two stages of development, that in wl
Gedanke and conscious reference were regarded as nee
imaginal carriers, and that in which the presence of co
admitted, but any effectiveness on the part of such co
determining the meaning is denied. Bühler sums up t
tention in the sentence "It is not too much to say that
mean anything with anything."[65] E. Mayer, in agreeme
Ach, adds his testimony, admitting that Bekanntheit is
theit der Beziehung. He furthermore contends that
ductionen nur ein Begleitender Umstand des Weiderer
sind."[66] And Watt is of the same opinion. "Doch da
theorie Reproductionen und sonstige Prozesse nur als Beg
schsinungen der Wiedererkennen auffassen, den es mu
betont werden, dass keine denkbare Gesetzmässigkeiten u
Vorgängen beim Wiedererkennen je den Bewustseinsinha
dererkennung Erklären werden oder können. Denn das
sein dass ich wiedererkenne ist immer etwas ausser den
Grunde liegenden oder sie begleidenden Vorgängen. W
kennen ist als Bewusstseininhalt ebenso primär und une
wie Rot oder Lust."[67]

In the case of Bühler the doctrine is perfectly clear.
is no sort of a specific content which necessarily media
consciousness of old or of new. The others are more amb
When Watt says that no laws of "Vorgängen beim W
kennen" can ever explain recognition, this may mean t
cognitive distinction as such cannot be explained on tha

[64] *First Book in Psychology*, 1910, p. 127.
[65] *Arch. f. d. Ges. Psych.*, IX, 1907, p. 362.
[66] *Untersuchungen z. Psych. u. Phil.*, I, 3.
[67] *Arch. f. d. Ges. Psych.*, 1906, VII, (Literaturber.), p. 25.

or it may mean that there is no structuralistic or content mediation. There is no experimental evidence drawn from work on the perceptual level which is directly, as a whole, favorable to this hypothesis of unmediated reference. On the other hand, all experimenters report cases in which no mediating content was observed. Many of them seek to get around the difficulty by having recourse to the subconscious. There remain, in spite of this rather mythical attempt, instances which are undoubtedly stubborn, and refuse to submit to analysis with any of the concepts so far employed.

d. *Conclusion in View of Extant Experimental Results.*

In conclusion, we may say that the whole trend of the discussion and experimentation has tended to establish the following points:—

1. The evidence is fairly conclusive that recognition is not exclusively the result of the comparison with a revived image of the same content. Still Lehmann, Katzaroff, etc., report instances where this occurs.

2. The evidence seems to prove that associations are by no means essential to recognition, although there are many cases where they are the mediating content. Gamble and Calkins, and Katzaroff, by citing instances where judgments of old do not result even when associations are present, and others where judgments of novelty and reproduced ideas coincide, make it plain that with some subjects at least, the mere appearance of the latter is not the carrier of the past reference. The correlation is not thorough-going enough. The possibility of some further differentiation remains.

3. There is much evidence in favor of a feeling of familiarity which functions in a goodly proportion of the recognitions. On the other hand, we find that even the most ardent supporters of the doctrine cannot isolate the tonus every time. No unanimity exists as to whether this feeling is an ultimate datum of consciousness or can be further analysed. In the latter connection, the evidence as to the universal presence of organic sensations and an affective tone does not all tend in the same direction.

4. All experimenters cite cases in which no peculia content can be shown to be present. A mere judgm "known" or "unknown" is the sum total of the reaction. results can be interpreted in two ways. On the one ha may have truly unmediated reference, a phenomenon whic agree with the tenets of the imageless thought school. other hand, and this is highly probable, the subject may n been aware of the content distinction to which he was r The general technique employed renders the latter view att Either there has been an effort made to work out the si in terms of one (or a very few) concepts, or the subject h left to himself to isolate what he could in describing perience. In either case, in the first owing to the limited of categories, in the second owing to the failure of the to note highly habitual and hence less striking aspects, t criteria may be overlooked. The hypothesis that the latt culty lies at the basis of much of the imageless thought r is tempting.

5. There is one final point which has not been noted that should be called to the attention at this place. Str Meumann both found that there seems to be an increase skill and accuracy with which the subjects employ peculia old and new content in isolating the latter, as practice pro This is a highly significant fact and we shall revert to it l

6. There are a few quantitative results which are of in this connection. Katzaroff reports the results of tim judgments, finding that sure judgments are returned more than doubtful ones, and also that there is no difference speed of judgments of oldness or newness.

Strong[68] finds:—

(1) The per cent of absolutely sure and correct juc decreases very rapidly at first, and then more gradually interval between exposure and identification is lengthened.

(2) As the interval increases, the certainty of the reco made steadily decreases.

[68] *Psych. Review*, XX, 1913, p. 1.

(3) Cases of incorrect recognition (a new stimulus judged old) are relatively rare as compared to the total number of correct judgments. Nor does the percentage materially increase as the interval increases.

(2) Theories of Ideational Recognition

So far we have been discussing theories which are concerned primarily with perceptual recognition, *i.e.*, recognition of objects present to sense. The subject of the difference between memory and imagination is one that has recently come to be of great interest. Waiving temporarily difficulties which may be involved in the statement, we shall take as a working definition the formula that memory images are those which represent or are referred to past sensory experiences as their antecedents, while images of imagination are those which have no such past reference. It is to be noted that with very few exceptions psychologists have considered the problem of recognition on the perceptual level as entirely distinct from that of recognition in the ideational realm. They have accordingly dealt with the questions separately and have set up hypotheses of a different type to explain the two phenomena. James is an exception to this rule. While not dealing with the matter explicitly, he shows by the whole trend of his teaching that he considers that the only differences involved is that in the one case the focal element or the content concerning which the judgment is returned is a percept, while in the latter case it is an image. Angell, Titchener, and Höffding are others who find the distinction to be one of the focal element and not of the actual processes involved. With these exceptions, the overwhelming tendency is to look upon the two processes as entirely separate and distinct.

Hume early laid down lines of differentiation that have persisted to the present time. He said that memory images retain the spatial and temporal order of the generating percepts, while images of the imagination have no such relation to past experience. Also, memory images are the more vivid.[69] The

[69] Treatise, Bk. I, Prt. I, §III (Selby-Bigge), p. 8.

former distinction is of course logical, telling us nothing of the actual processes involved; the latter is matter for investigation. The doctrine continued to be formulated in logical terms for a long time. For Bain[70] and Sully[71] the great point of difference is that memory revives a copy of the past, while in imagination we have a regrouping of elements. Bain in addition declares that in the latter there is always involved an activity of the will. We have already discussed James' theory of memory. The only distinction for him would be that the focal process is an image and not a percept. Höffding says that we have unaltered *vs.* altered grouping of elements as the basis of differentiation. Memory images are, however, recognized, a process which is the same on the ideational and perceptual levels.[72] Angell[73] is another author who believes that the recognitive reaction distinguishes memory from imagination images.

Jodl[74] sees in imagination the faculty of producing composite images through the addition of elements which did not belong to them originally, but which are easily associated with them. This adding may be the result of unconscious forces or it may be done consciously, as in the case of lying. Lipps,[75] while far from explicit in his doctrine in this matter, would, I believe, base his distinction on his doctrine of dispositions. A disposition might be defined as the tendency possessed by any content, which has once been present in consciousness, to reassert itself under appropriate conditions. Such dispositions may be considered as overlapping in so far as the content that they represent is similar. For instance, the dispositions of two tones of the same pitch and intensity but of different clang color, overlap in their common elements. Dispositions have, then, different "Seiten" or "Eigentümlichkeiten," which are capable of receiving a given "Bestimmung." In our illustration, we would say that the fact that all

[70] *L. C.*, p. 571 ff.
[71] *L. C.*, I, p. 362.
[72] *L. C.*
[73] *L. C.*, p. 225.
[74] *L. C.*, II, p. 162.
[75] *L. C.*, pp. 77, 83.

tones have some pitch represents one of the "sides" of its disposition, while any specic pitch would be the particular Bestimmung of that side. In so far, then, as different dispositions have the same "sides," the different specific "Bestimmungen" that they have exhibited are capable of being transferred from one to the other, even though such a complex has never been experienced in the perceptual realm. That is, if I should transfer the clang color of one tone of a certain pitch and intensity to another tone of the same pitch and intensity, but of different clang color, the second note may be conceived of as being qualified by an altered Bestimmung on a "side" which it possesses in common with the first, namely, the tendency to have some sort of clang color. This is, of course, a purely logical formulation. In another place, Lipps speaks of imagination as the capacity to arrive at results from premises without the necessity of traversing intermediate steps.

Baldwin[76] believes the recognition of an image to consist in the reinstatement of its apperceptive relations. The doctrine has already been discussed. Wundt[77] differentiates memory from mere renewal of content. In memory proper, we have the image recognized and brought into relation with the rather permanent ideas and feelings which constitute the nucleus of the consciousness of self. We also have a relatively exact representation of earlier experience. In imagination, there is a change in the arrangement of the Vorstellungen. As this also takes place to some extent in memory, the real differentium lies in the fact that in cases of the latter we have a free and untrammeled run of images mutually connected in accordance with the laws of association, while in the case of imagination, the connections established always involve a guiding purpose and an activity of the will, be it ever so rudimentary.

Külpe,[78] representing the Würzburg school, can find no difference whatsoever as far as the content and modes of psychic functioning are concerned. He says, "No mental process is in-

[76] *Senses and Intellect*, p. 176.
[77] *L. C.*, III, p. 631.
[78] *L. C.*, p. 188.

trinsically a recollection or an imagination; no special cl
sensations has the exclusive privilege of subserving m
A certain content becomes recollection by a judgment con
with it, and this judgment can be produced by extremely
ent causes. Imagination, in the same way, is characterized
the appearance of particular sèries of sensations or ide
by the realization that the given ideas represent somethin
never before experienced in this form, but possibly to l
ceived in the future." Still Külpe seems to believe th
memory image resembles an earlier experience as regards
and temporal and spatial disposition, while an imagination
does not. The difference is not, however, indicated by any
diate peculiarities of content.

Titchener[79] recognizes explicitly that the only differer
tween recognition on the perceptual and on the ideational
that the focal process, the process remembered, is in the o
a perception and in the other an idea. He goes on f
however, to give a description of certain structuralistic
ences between the two types of images which is based on I
work.[80] This is the first experimental research in this li
has come to our attention. Spoken words were used as s
the observers being instructed to give themselves up
visual imagery evoked, allowing it free rein. As a re
the introspection, Perky distinguishes sharply two differen
of images, (1) on the one hand, images of recognized a
ticular things, figuring in a particular spatial context on
ticular occasion and with a definite personal reference, a
images with no determination of context, occasion or p
reference (imagination image). The following differenti
noted.

1. In the great majority of cases memory images i
gross movement of the sense organ with which they are c
ted, while images of imagination entail steady fixation.

2. Images of the imagination involve a mood of s
images of memory a mood of recognition or familiarity.

[79] *L. C.*, p. 413, ff.
[80] *Am. Jour. of Psych.*, XXI, 1910, p. 422.

3. Imagination images are substantial, complete and often highly colored, while memory images are scrappy, fleeting and filmy, sometimes spoken of as colorless etchings.

4. Memory implies imitative movement and correlated organic sensations, while with imagination we have kinaesthetic and organic empathy.

5. Images of imagination arise more quickly, more suddenly, and more as wholes, and persist longer and are less changeable than are the images of memory.

6. Memory implies roving attention and a mass of associative material, while imagination involves concentrated attention with inhibition of associates.

The next experimental work that appeared was that by Martin.[81] The subjects were instructed to project visual images of the two types side by side. It is difficult to see just how far the distinction between memory and imagination used by this experimenter is comparable to that of Perky. One of the main sources of confusion was that her subjects were allowed to frame their own definitions, *i.e.*, they received instructions to arouse images of these two kinds, but were furnished with no working basis of differentiation. In general it seems, though, that the basis for differentiation was that memory images were recognized as representing an earlier experience. In a footnote, Martin says that recognition was probably the most decisive factor. Even this, however, leaves doubt as to just how far her criteria are comparable with those of Perky, and, as a result, how relevant her criticisms of the latter may be considered to be. At any rate, she was able to substantiate none of Perky's results, and finds only two possible points of distinction.

1. The memory image generally comes first.

2. The memory image is generally accompanied by more associates and Nebenvorstellungen.

Ogden[82] has recently reported experiments along the same line. The criterion of differentiation used was that of familiarity. Again it is a question as to how far this allows his re-

[81] *Zeit. f. Phys. u. Psych.*, 61, 1912, p. 321.
[82] *Am. J. of Psych.*, XX, 1913.

sults to be considered as comparable with those of Pe
Familiarity, on further logical analysis, may have a numbe
degrees of connotation. It may, for instance, mean merel
awareness that I have experienced the object at some ea
time. In this case, the definite reference to a particular tim
place utilized by Perky would be lacking, and it is dou
whether results based on such divergent series can in any
be considered as comparable to one another. Working
words as stimuli, Ogden obtained results which substa
those of Perky in one particular only, namely that me
images tend to be located at a distance, while imagination in
are in near-by space. He finds in addition two differences:

1. In contradiction to the relationship established by P
the memory images are found to be distinct in a larger nu
of instances than are the imagination images.

2. The average reaction time for the memory images i
ticeably less than for the imagination images.

From these results, Ogden concludes that the experim
criteria established do not afford adequate grounds for a d
entiation of memory and imagination in terms of content.
believes that the differences are really matters of meaning,
are not "capable of complete reduction, either to certain ch
teristic and invariable sensory and imaginal attributes, or
certain contextual setting, which may in turn be analyzed
terms of sensory and imaginal content." In addition, O
reports that there were many cases where a feeling of famil
could not be found to be an accompaniment of the me
image. "Very often the observer reported an image as fa
or strange, but could detect no feeling attached to the e
ience." Although he mentions cases where associated i
and ideas are the basis for the judgment, the general evi
of his own work seems to Ogden to substantiate the doctri
forth by Külpe, which we have already quoted, to the effec
an image becomes a recollection through a judgment con
with it, not in virtue of any peculiarities of content. An
same is true of constructs of the imagination.

Koffka[83] reaches the same conclusion as the result of his work. He rejects Perky's criterion of personal reference and divides the images found, not into the classes of images of imagination and images of memory, but into general and particular images. The latter represent individual objects, the former do not refer to any specific object or event. His results are, therefore, not germane to the general problem in hand. It is of interest to note, however, that he also can find no differentia within the structuralistic content.

In conclusion then, we may say that the experimental work so far done has led to no unanimity of opinion. This is, we believe, largely due to the fact that the basis of distinction employed has not been the same in any two cases.

[83] *Über die Vorstellungen und ihre Gesetze*, 1912.

II. THEORETICAL DISCUSSION CONCERNING L CAL ASPECTS OF THE PROBLEM OF RECOGI TION AND CONSEQUENT ASSUMPTIONS RELATIVE TO EXPERIMENTAL TECHNIQUE

In view of the great diversity of theories that have advanced and of the lack of agreement among experime it is evident that a thorough investigation of the whole su of recognition is requisite. This is the aim of the present n graph. Before setting forth the results of the experiments formed however, we desire to call the reader's attentic certain very significant conclusions that are called forth logical analysis of already established facts.

1. Except in the few cases already indicated, authors very generally taken for granted that there are two problen recognition that must be treated separately,—that of perce and that of ideational recognition. The mode of treatmen certainly been (although the fact usually is not explicitly st to regard these two forms of recognition as two absolutely tinct phenomena,—as different as are sensations and affe elements. Külpe will serve as a good illustration of this tice. He attributes the recognition of a perceptual obje the presence of a peculiar mood, while, on the other han attributes the recognitive element in memory images to a ment connected with them. He thus has one explanatio recognition in perception and a totally different one for r nition in the case of memory images.

This general assumption that recognition in the case of ception is one phenomenon and that in the case of memory a totally different phenomenon requiring a different mod explanation, seems untenable. Because the content recog in the one instance is different from what it is in the oth does not at all follow that the processes of recognition are ferent in principle. On the contrary, as the experiments reported will show, recognition must be regarded as the

in principle regardless of whether the content recognized is perceptual or ideational. Whether a perceptual object is old or new may be decided by an observer by means of an ideational criterion like the stability of its image; or it may be decided by him through a sensory test, such as the presence of motor phenomena. In like manner, an observer may distinguish between a memory and an imaginary object, either through sensory or imaginal processes. For instance, he may recognize a recalled date either by ease of articulation or by some characteristic of its visual image. There is, therefore, no difference in kind between the types of content that may serve as criteria of oldness or newness in the case of perceptual and ideational objects. Both perceptual and ideational recognition may thus be mediated on either a sensory or imaginal level; the mediating process may be the same in both cases, the difference consisting wholly in the kind of object recognized. It is absolutely impossible to say on *a priori* grounds in any particular instance whether the judgment will be due to sensory or imaginal factors. This will vary from individual to individual, and for the same individual at different times and in different experiments.

2. Again it is clear that the majority of theorists have considered that we have recognition in memory, or, in the perceptual sphere, when we are conscious that we have experienced an object before, while in all other cases it is lacking. Take Höffding and Angell. For the former, it is the presence of revived images that constitutes recognition and lack of them that accounts for its absence. The latter seems to believe that recognition marks off memory from the reproductive imagination. The distinguishing mark is the presence of something in the one instance that is lacking in the other.

Further analysis convinced us that this view is erroneous. Recognition is present in both memory and imagination, both with objects judged old and with those judged new. We recognize a hat as one we have seen, or we recognize a machine as something foreign to our past. It is a matter of what is recognized, not of the presence or absence of some given factor or process. In fact the whole point is well brought out by saying

that recognition is merely a specific form of cognition. we are conscious of oldness we are re-cognizing, cogni content as having been perceived before, while when we something to be new, we are cognizing or thinking it as f to earlier experience. The presence of a definite mean obvious in both cases. The difference is in the specific co qualification or Auffassung concerned, not in the prese absence of some psychological process. Moreover, these ments of oldnesss or of newness are merely special cognit actions, in every way on a par with the awareness of pr or absence, kind, difference, likeness, quality, etc. As cognitively react to objects as trees or as animals, as big little, as similar or as different, so I may react to them or as new. This does not signify that there are no diffe of content in evidence when diverse judgments are ret There are objective differences between the tree and the which parallel the differences in the concepts applied. J there are (presumably) differences in the content present judgments of old or of new are returned. The point i we do not have these differences plus a unique type of re unlike any other processes encountered in the realm of ps ogy, but these differences plus a meaning distinction wh on a par with numberless other meaning distinctions.

3. In recognizing objects as old or as new, we are judging concerning fixed definite relations between certain In memory we never remember an isolated object, such tree, but always *something about* that object. The obj memory can always be expanded into a declarative sentenc subject and predicate terms. We remember that the *tre* *large,* or tall, or green, or in the corner of the yard, or tree which we saw. There are always specific relations be terms. These may be of various kinds. In our illustration are those of magnitude, quality, spatial position, of subje object. In like manner, in imagination we are always cerned with the *alteration* of some specific relation or gr relations. When I conjure up the image of a winged dog the juxtaposition of the dog's body and of wings is ne

the terms themselves. The same holds true in perception. When I recognize my hat, it is always some specific relation or relations which constitute it an old object. It may be the spatial, quantitative, and qualitative relationships of a broad brim, a high crown, a narrow ribbon of a particular hue and material. The doctrine at present current in psychology that all imagination consists in the novelty of combination of old elements is evidence in favor of the truth of this contention. The terms as such are never the basis of the decision, a strange hat is made up of familiar components. What makes this actual difference between my old hat and the new one of my friend is that the one embodies certain relations that the other does not. Owing to this, I judge that the one object is familiar, the other not.

That this doctrine is valid is seen by the fact that where no specific relations are involved, we never cognize the object as old or as new. We have rather on the ideational level the general idea or conception, and on the perceptual level the mere consciousness of the class. I abstract from any specific relation and merely concern myself with certain large general relations between terms. I think of a dog; this would be a general idea. Now in contrast to this general idea, suppose that I recall that a specific dog of my acquaintance is small and white, or suppose I imagine that a dog has wings. In case of the general idea I merely thought of a four-footed animal with a certain body structure, etc. The process of rendering one or more of these relations specific effects the transition from a general idea to a memory on the one hand and the process of altering one or more of these relations would change the general idea into an imagination product on the other.

Likewise in perception. The difference between a hat, my hat, and a strange hat is the difference between confining the attention to certain omnipresent relations peculiar to the class and neglecting the individual manifestations in the existing instance, and isolating certain specific relations which constitute the object either a familar or a strange member of the class. It will be understood that we are in this section discussing the concrete meanings in these different cases, the *what* I am con-

scious of, and are neglecting for the moment, the pecul of *content,* if any, which bring it about that these different are cognized. We reiterate, then, in conclusion, that in m imagination, and perceptual familiarity or strangenesss, tual object involved is always a unitary complex whole co of differentiated parts and attributes standing in specif tions to each other and that novelty or oldness refers relations involved.

It follows then, that any complex whole may consis larger number of parts united in many relations, some o are new and some old. The proportion between the tw may vary for different objects. In fact, in any concre we are always dealing with a situation in which these as novelty and of oldness co-exist. Any judgment returned always relevant to some limited number of relations. T content may be judged old and rightly so if one particula is singled out, or new with equal correctness, if another lated. Thus, if I am asked whether I have ever seen a book, my answer would be entirely different according terpreted the question. If I understood the interrogato interested in determining whether I had ever seen a combination of a number of leaves of a certain size, a c a certain hue, and words with certain definite meanings outside, I might answer "yes." If, on the other hand, I stood him to be interested in whether I had ever see elements on a certain desk at a certain hour of the day certain arrangement of light and shadow, I might sa The subject himself may not be aware of this analytic stracting activity, may in fact not know what particular is the object of his estimate, may not know in other wor relation *is the object* for him. But the selective activit tention guided by the dominant interest of the momen other factors which stress particular aspects of the total will always insure the specific reference of any particul ment. This inability of the subject to point out wh actually reacting to is well illustrated by such instances a the sailor feels that the boat is not riding correctly, th

cannot tell why, and the case reported by Whipple where a subject thought that he was reacting to pitch but was really influenced by the time elapsed. The fact is also notorious in the motor reactions to percepts.

It may occur to the reader at this point to object that the idea of a giant is usually spoken of as an imaginary idea, and that this is not the idea of a complex in which certain concrete relations have been changed. The whole structure seems novel. In reply it may be pointed out that there is a fallacy involved in his objection. Such ideas are in the great majority of cases either conceptual or memorial, usually the former. They refer to past ideas or pictures, etc. In so far as there are no specific relations singled out and rendered concrete objects of memory, they are general in their reference. If we have not actually seen pictures of giants we have at some time built up an ideational complex step by step by bringing terms into new relations. We really at that time imagined the object. But the child of the constructive imagination, constructed yesterday, becomes memory today if we remember specific relationships established on the former occasion, or conception if the relations are more general. We must then be exceedingly wary of employing as a means of getting imagination products, words which refer to or mean objects that, once imaginary ideas, have become memories or conceptual objects. Such general ideas of imaginary products or such memory ideas of past imaginings, are what Ogden's stimuli are adapted to bring out. And in so far it is a question if his actual results are relevant to his problem.

The implications of this analysis for experimental technique are significant. If the subject is practically always confronted with a complex which embodies some old and some new relations, and if he is sometimes in the dark with regard to what particular aspect he is reacting to, we are forced to make the problem definite in experimenting. This may be accomplished by altering only one phase of the complex at a time, and then either indicating to the subject what this aspect is, or forcing him to return an explicit judgment concerning it, even though ignorant of the locus of the change. Any other procedure leaves

us with results which are incomparable *inter se*. Take
ample the woman's hat and the book which Martin as
subjects to image, and consider the following hypothet
scription of what our analysis leads us to believe oft
place in the course of her uncontrolled work. In both
may have occurred that while the colors imaged were t
the past concrete experiences, the relative size of differe
of the complex image was abnormal. The subject judgi
cerning the quality in the case of the hat may have class
image as a memory product, while the abnormal propor
the book led to its being regarded as an imagination ima
he is often unable to specify correctly the phase reacted
subject may have had his attention drawn in both inst
the unaltered relation under the impression that this
efficient aspect. As a consequence, he would naturally
the same peculiarities of content with both objects. W
have then, different judgments, the same content, and n
ence discovered between memory and imagination image
is a probable explanation of Martin's results. In othe
some of her objects were ambiguous, and might be c
judged either as products of the imagination or of mem
cording to the particular aspect of the whole which eng
subject's attention.

Where, however, there is only one relation altered a
and this is either specified to the subject or he is forced
explicitly concerning it (*vide* our unknown series), th
tion will be the object reacted to in the majority of case
all cases the peculiarities of content involved in cognizin
be the center of attention. There is, of course, even
chance that while attending to the specific relation the s
reacting to another aspect. In as much, though, as there
one relation altered, the judgments of novelty, since the
the great majority of cases correct, *i.e.*, occur with alte
tent, must be relevant to this relation. Again, since the
of old judgments occur with unaltered content, the sa
must be true for them. While on account of the compl
the situation, we can never be absolutely certain that th

fied relation will be the one reacted to, the fact that there is always a high degree of correlation between the judgments and the status of this particular aspect, indicates that calling the attention of the subject to a phase of the total situation prior to the presentation will insure its being the point of estimate. By virtue of the fact that the attention of the subject is concentrated on this point, whatever peculiarities of content are present with the different judgments should then be brought out clearly in the reports. The subject himself may not be able to isolate the differences. The experimenter will, however, be able on the basis of a large number of cases to establish a correlation between the meanings and content of particular types. The same result would be obtained even where the subject does not know what particular aspect is altered, provided he is forced to judge explicitly concerning all the crucial relations. In so doing his attention is directed to each one in turn, and the content that accompanies the awareness of any aspect is thrown into relief. We can, then, see whether there is any peculiarity of this content present when judgments of old or of new are returned.

So far in our analysis we have been abstracting from one relation which is always involved in recognition of oldness. It is not merely a question of whether a specific relation among terms is old, but whether it is old for me. This *personal reference* is present in every cognition of oldness or of novelty, either implicitly or explicitly. It is generally implicit. If I judge a certain combination of colors to be repeated, I often record my decision with such sentences as, "That is old," or "I know that," in which no overt indication of *my* earlier experience is contained. But these modes of expression always point to such an earlier experience or to the subject's past as one of the terms essentially concerned. For to be old, means to be old for the person judging, to be known, means to be known as a result of earlier contact, and to be habitual means to be habitual for the subject. On occasion this personal or perceptive relationship is explicitly indicated. The subject says "I saw that red house before." Here, as is generally true, we have another

relation (house-redness) besides that of the personal experience. In a few cases, this second or objective relation is altogether lacking, and the personal reference only appears. The judgments are always what we may perhaps call sensational, *i.e.*, the objective content is so reduced as the result of abstraction that the subject merely considers some sense quality, or other highly abstract phase of the presented field in the relation to his past experiences. The decisions take the form "I smelled that before," "I recognize that taste," "I saw that green," etc.

4. It follows from the above discussion that any old relationship between terms is to some degree habitual, while novelty of combination violates habit. We believed then that this difference might afford us a clue to a possible line of demarcation. This difference would, of course, be one of degree. There may be old relations which are not thoroughly habitual, as they may not have been experienced often enough, while there are new ones which do not violate habit very greatly.

5. Habit has always been an important category in psychology, but in application it has generally carried a physiological connotation. *A priori* this appears to be a detrimental limitation of a highly useful conception. Effects of the reinstatement or the violation of customary relations of terms or other conscious content should be clearly observable on the psychological side. From a physiological viewpoint we speak of an habitual reaction as quick, easy, with all the various component movements linked into a series marked by smoothness and facility of sequence, susceptible of repetition and prolongation in a more or less unaltered manner, and apply contrary conceptions to non-habitual responses. So likewise, we anticipated that wherever the subject was face to face with a situation calling for reflective manipulation and characterized by habitual or non-habitual relations, a series of similar descriptive terms would be found to apply to the conscious processes involved.

A truly psychological connotation for the term habit can be found, if we are correct in our surmises. Nor are we limited in the sphere in which we may search for habit manifestations. Any phase of the content may show these habit characteristics.

Differences of intensity, ease of arousal or of maintenance, stability, permanence, immediacy of appearance or delay, any of these and other aspects could embody the workings of the principle of habit and serve as a basis for differentiating the novel and the old. The aim of our experiments was to test this hypothesis.

6. Logical analysis allowed us to reach these formulations of the nature of the problem involved in recognition and to anticipate the probable line of solution. With this as a background, we made certain important assumptions which influenced our experimental procedure, and which our researches were designed to test. In the first place we assumed that all logical distinctions, (of meaning) are paralleled by a corresponding series of psychological or content distinctions. This means that, in this case, we believed there are certain peculiarities of content which can be shown to be present with a judgment of oldness and to be lacking with a judgment of novelty, and vice versa. The business of mind in its cognitive phase is to secure logical distinctions. This is thought regarded from the functional point of view. One of the main tasks of psychology is, we believe, to explain if possible how the mind is enabled to draw these cognitive distinctions, *i.e.*, how the mind functions. We assume in our hypothesis, that these thought differentiations are made in view of certain peculiarities of content. This means that structural and functional psychology would parallel each other, and that the structural distinctions are the means employed by the latter in explaining its phenomena. Content and meaning would stand in the relation of cause and effect. We would thus have a causal explanation of certain mental phenomena in purely conscious terms, with no need to appeal to physiological hypotheses for our immediate means of elucidation.

In opposition to such a theory as we have just outlined, stands the whole doctrine of those who advocate contentless thought. In their view it is true that the mind cannot make distinctions without the presence of any content whatsoever, but the content which is observable is not relevant to the judgment rendered, *i.e.*, does not mediate the reference. Structure and function are in-

dependent variables in the sense that they are not found t
concomitantly, they manifest no intrinsic relation. The
tion from Bühler in the historical part of this paper brin
the distinction admirably.

The hypothesis put forward does not assume that the
lelism is necessarily between some kind of specific meanin
a peculiar *qualitative* distinction in the content, as is
done. We assume rather that any phase of the content
any complex of contents may serve to mediate the cogniti
action. The relation between structure and meaning is a
phase of the stimulus and response situation, and any asp
content which can stimulate a specific motor or verbal re
may likewise carry a specific meaning. In our work th
are not limited merely to attributes of elemental artifac
to qualitative distinctions. In fact in perceptual experienc
of the following may be the stimulating aspect reacted to:
ity, as when I name various colors differently; Size, as
select nails of different sizes in doing a piece of carpenter
Form, as when I differentiate between a circle and a s
Position, as when I vary my reaction to a street car acc
to whether it is a block away or very near me; Intens
when the hunter prepares to shoot as the noise made by
proaching animal becomes very loud; Behavior, as when
nis player uses different strokes according to the way t
bounds; Context or the presence of associated materials as
a fire in the grate incites a very different reaction from
on a rug. It is of course obvious that any specific combi
of these factors may be reacted to. Diverse motor and
reactions to objects which differ in any of the aspects nam
thus seen to occur in actual life. We believe the same
true in the case of all thought distinctions, *i.e.*, that di
meanings are mediated by contents which differ among
selves in regard to any of the characteristics mentioned.

This whole assumption regarding the parallelism of t
and content is to be tested by the course of the work unde
herewith. The vital point at this juncture is to note t
start out believing that there is no valid reason for limiti
types of criteria sought.

Although we believed the cognition of oldness or of novelty to be mediated by specific content distinctions, it does not follow that the subject must therefore be aware of this fact. There may be several degrees in the subject's ignorance: (1) The subject may be unaware of the bare fact of mediation itself. This result will be found to occur most frequently in perceptual recognition, where the object is immediately classified as new or as old, and where there is no sense of any dependent relation between the judgment and the content. The judgment is there, given, and defies further analysis. (2) The subject may be convinced that his judgment was mediated by some phase of the content, but be absolutely unable to point out the specific determining factor. (3) Lastly the subject may not only be conscious of the mediated character of the decision, but he may also attribute it to a certain definite characteristic of the content. This does not imply that he is by any means necessarily correct in the latter phase of his judgment. He may report with a high degree of certainty that his judgment of novelty was based upon the instability of a visual image, and yet be wrong. This error in isolating the efficient element of content would not necessarily entail an error in his judgment regarding the oldness or novelty of the situation. The correlative judgment may be wrong while the latter is correct.

Two very important negative propositions concerning experimental procedure follow from the above assumptions: (1) All upholders of the doctrine of the non-mediated character of the recognitive reaction rely wholly upon negative introspective evidence. All experimenters have reported many cases in which correct judgments of oldness or of newness were returned, and yet the *observer* was unable to detect a content basis for the judgment. This absence of any *sense* of mediation leads to the conclusion that mediation was not present, a doctrine based solely, as we have already indicated, on the negative fact that the subject could not detect the circumstances unaided. The only proof of the non-mediation doctrine that is offered lies precisely in these negative statements, a line of argument the validity of which we deny.

(2) When mediation is felt to be present, experimente
dealing with the problem of the particular content basis c
mediation, have habitually relied upon the subject's introsp
analysis of the correlation. We, on the other hand, shall
reasons for doubting that these reports are necessarily
That they are generally correct must be admitted, but the
on occasion subject to grievous error, and hence conclu
based on introspective reports alone, unchecked by other r
(the usual manner of experimenting to date) may be mislea

Our technique is characterized by the objective comparis
two sets of data in the attempt to establish a correlation b
method of concomitant variation. The subject (1) repor
decision concerning the oldness or newness of the stimulu
(2) describes in all possible ways all the content phases pr
during the total experience. After taking a large numb
such reports, the experimenter (not the subject) attempts a
relation between a specific judgment and different aspects o
content. If a judgment of novelty is present whenever
bility of the visual image is reported, while judgments o
ness accompany stable images, we conclude that a causal re
exists, that mediation is based upon the stability aspect o
image. This is the only and final test of the theory of m
tion—of a causal dependence of meaning upon content—th
invariable concomitance.

That mediation, causal relation or *invariable* concomitan
tween meaning and content can exist without the subject'
mediate awareness of the fact, is evident on a moment's refl
to one conversant with scientific modes of procedure. In
science, such as chemistry, a result is observed along w
great mass of concomitant phenomena, among which the s
ist knows the cause of the occurrence is to be found. But
moment and without further manipulation the investiga
at sea as to the particular phase of the total situation wh
the cause in question. In order to isolate the latter, he
either vary the totality of the phenomena before his eyes
the sequence of cause and effect is immediately observed,
may record the events and compare this record with a large

ber of other instances where the effect was noted and thus determine the common antecedent present in all of them. The same situation confronts the introspecting subject. He reports a result—a judgment, of novelty or oldness,—and at the same time he observes a highly complex series of content processes. Why should a naïve observer be supposed to suspect a causal correlation between the meaning and content sides of his total reaction, let alone to determine the particular aspect of content involved?

In fact the subject can immediately suspect and observe a causal nexus or correlation between his judgment and the accompanying content processes only under special and unusual conditions. These include the following factors, a period of doubt and delay following the presentation of the stimulus, a series of variable processes on the content side in evidence during this period and an immediate judgment following a specific change in the content. Suppose for instance that the observer is in doubt as to whether the stimulus is old or new, and during the moments of hesitation, an associate train, a particular mood, a peculiar motor reaction, all come in without relieving the stress. Suddenly a visual image of the stimulus appears and right on its heels comes the judgment that the object is old. Here the chances are very great that the subject would believe that his decision was mediated by a very specific bit of content, the visual image. This might not be the actual basis of the reaction, but we would have here a definite sense of mediation. As we have said, the validity of this introspective correlation would have to be tested by more objective methods later.

On the other hand, suppose that during the initial period of doubt, a complex content composed of visual images, moods, associative trains, organic sensations were present, and that all were changing in various ways, or that a number of them put in their initial appearance at the same time. Suddenly the subject comes to a decision. As there were a number of aspects of the content in simultaneous change just prior to the solution of the difficulty, he may be sure that some of the variations were concerned in the result but necessarily is incapable of determining

which change was responsible. There is thus a sense of
tion, but no knowledge of what the actual basis of the react
In the case of percepts having no ideational or central con
ant processes, the elements of content changes is lacking.
ceptual content is given, fixed, hard, and unyielding. F
characteristic of the central activities only. Therefore the
of mediation must be lacking where only the perceptual c
is present previous to the judgment. All that is in evide
fixed sensory content plus meaning. It is precisely such
which furnish the ammunition for the defenders of the
of non-mediated reference. Our present analysis show
mediation even though present would escape the subject
these conditions.

Under these conditions, mediation or causal nexus can
immediately sensed or observed, it can only be inferred fr
objective or memory comparison of a large number of ca
which content variations have been introduced. If the s
then found a parallelism between his judgments and certa
culiarities of the percepts, he would be justified in trac
causal connection between these two phases of the situatio
in saying that the sensory peculiarities themselves mediat
judgment. In other words, the subject in order to establi
fact of mediation would have to resort to the techniqu
ployed by the present experimenter. We obtained a doul
port, as to meaning and as to accompanying content, and
on the basis of a large number of cases determined the
lations. We always received the subject's report as to th
correlation, but these reports were taken as final only whe
were verified by our objective results.

8. Also to bring out the factors involved we must use
ever possible, extreme cases, cases where the relations are
ingly old or strikingly new. That is, we shall take ins
where the violation of the old system is very marked and
lack of alteration is equally notable. Moreover, in dealing
this material, we shall try, in the majority of experimen
create a situation in which there is a high degree of doubt,
alternatives are present, where, in fact, the subject is for

reflect and call in all possible aid in order to reach a decision. This will tend to throw the peculiarities accompanying both meanings into relief, to make clear the fact of concomitant variation, and, especially where the subject is dealing with first a new and then an unaltered object, will emphasize the processes involved.

It is exactly here that many of the earlier experiments are defective. Take for instance the work of Bentley and that of Whipple. The latter's maximum interval between standard and test seems to have been 60 seconds, while the former never exceeded five minutes except in a very few cases. Moreover in both cases the subject in the second presentation knew what he was looking for, was all primed for his response, and when the stimulus came it fell right into a prepared groove. Abramowski's maximum interval was five seconds, etc. It was obvious that such procedure as this is not well calculated to bring out the factors involved. The stimulus is almost a part of the subject's present mental furniture, and there is practically no doubt. This will always lead to the overlooking of the mediating content. Where any action is too habitual and quick we experience great difficulty in observing what takes place. We shall see that in the following experiments this difficulty was avoided.

III. EXPERIMENTAL SERIES I, THE RECOGN CONTENT BEING PERCEPTUALLY PRESEN

(1) General Technique

In working out a technique for experimentating on th lem we have been discussing, we were guided by four m They have already received some consideration in the pre section.

1. We desired to observe recognition as it takes place conditions which are adapted to bring out the essentials process and where the dependence of the subject upon pe ties of content which we believed to exist would be most o provided our hypothesis should prove tenable. Such a tions is, as we have already said, to be found where t doubt and a subsequent decision following on deliberati thought. Further assistance was to be anticipated from st the old and the new situations in contrast. Under these tions, the chances of overlooking phases of the total si which are the real bases for the reaction are reduced to a mum and even where they are not indicated by the sub being the efficient stimuli, a careful examination revealin invariable presence when one decision and their invaria sence when the other is returned, will give us a means of lishing their true status.

2. In order that the latter result may be achieved and t subject's own belief may not be the only basis we have tablishing the correlation between structure and functi need a method that will ensure the direction of the atten as many phases of the process as is feasible. By this we that introspection should be obtained on as many points subject feels himself able to report upon without falsificat results due to the fact that the experience is constantly r ing in time as the report proceeds. Moreover, in this w can be sure that the different points are reported in ever and can thus know how far any result is typical and not a chance appearance.

3. We also desired to employ as many different kinds of material as possible, and to vary the particular changes of relation between elements used to give us our novel stimuli. This procedure was, of course, calculated to avoid generalizations based on isolated peculiarities. In this connection, however, it hardly needs to be mentioned that we did not employ meaningful material.

4. In order to control the factor actually reacted to, we altered but one specific relation at a time. In this way we avoided ambiguities and were sure that our results were comparable *inter se*. Moreover, this relation must be sufficiently simple and easily understood so that it can be pointed out to the subject when necessity requires. This will insure his turning his attention to the vital problem in hand, and neglecting other factors which might lead to confusion.

In order to realize these conditions, we adopted the following technique in our initial series of experiments. Six pairs of (1) nonsense syllables, (2) letters, (3) geometrical forms, (4) small squares of colored paper, (5) three-place numbers, were mounted on cards. On each card there was only one kind of material, *i.e.,* in no cases were nonsense syllables mixed with letters, etc. The pairs were placed, one below the other in such a way that they could be presented in temporal sequence. The exposure apparatus used was the drum commonly employed in memory experiments.

The pairs were presented one at a time, each presentation lasting five seconds. In this way the subject was given an opportunity to go through the series of six only once. There were no restrictions as to the method of learning except that the subject was not to seek associations. No effort was made, however, to prevent the appearance of such as spontaneously offered themselves.

After the subject had been given one series of six pairs, there was an interval of an hour. No restrictions were placed on the way this intervening time should be spent. As a matter of fact, the subjects generally spent it in study, working about the laboratory, etc. We thus approximate the conditions of ordinary

life. The instruction was, however, given not to recall t terial and think about it during the interval.

We chose to use an interval of an hour as we had fo preliminary work that this period was well adapted to the condition of affairs that we desired, namely, a state o in the case of a good proportion of the pairs, without same time rendering all intelligent judgment impossib placing the subject in a position where his decisions we better than guesses. We had, in other words, a situation the subjects were neither so sure as to be unable to note the factors involved in the decision, nor so doubtful as move all real validity from their choice.

At the end of the hour the material was re-presented following changes were made:

1. The spatial order of the individuals in a given pa changed, *i.e.*, if the pair had been x - y before, it was now as y - x. This we called a change in order.

2. New pairs were made out of individuals which h been together in the first presentation, *i.e.*, if we had tw *a, b* and *c, d,* when the material was presented, we now pairs *a, d* and *c, b*. The individuals were always left on that they had been on in the initial series. We called alteration a change of arrangement.

3. New individuals were introduced. The new ind could be either the first or the last member of a pair o might be a completely new pair interpolated. This was a change of individuals.

Only one of these changes was made in any given ser on re-presentation changes of order were introduced, no either of arrangement or of individuals were present. were always three old pairs and three new pairs in every the places where they occurred being constantly varied subjects at no time had any knowledge of the number of made.

There were two methods of procedure, with and knowledge. In the former case, the subject was told th one change would be made in the re-presented series a

also informed as to the exact nature of the change, *i.e.*, whether it would be a change of order, arrangement or individuals. In the procedure without knowledge the subject knew absolutely nothing except that changes of some kind could be expected in the second series. It is obvious that in the latter case there are three judgments involved in every decision, *i.e.*, the subject would have to decide about any given pair whether (1) he had seen the individuals, (2) he had seen them together, (3) he had seen them together in the same order.

With changes introduced as described above, the subject was given the re-presented series. Each pair was exposed for five seconds, unless of course the subject came to a decision before the end of that time. At the end of five seconds, the shutter was closed. The subject then reported his decision if he had made one, and if not was allowed to think the matter over, the stimulus being, of course, removed, until he either came to some conclusion or reported that decision was impossible. A number of times in the course of the experiment the material was exposed again for a few seconds at the request of the subject. This happened rarely, however. As far as our problem was concerned this second exposure made no difference whatever as we were interested in the introspective reports, not in the quantitative phases of the matter.

After the subject had indicated a decision, the following questions were suggested by the experimenter as a means to getting as complete a statement as possible of the processes involved in the reaction.

1. Are you sure of your decision, or are you in doubt?

2. What kind of imagery are you using?

3. Is the group present at once in the focus of consciousness, and do you decide on the basis of the group as a whole, or does the attention feel its way from one individual to the other? Does this involve a fading of the former into the fringe?

4. Do you try any other order or any other arrangement, (varying with the specific change indicated)? Do you work over this pair a number of times?

5. If you get the individuals in a temporal sequence, and not

as a unit, is there any noticeable ease or lack of ease in
the second follows the first, *i.e.,* is the articulatory or a
etc., sequence noticeably smooth and spontaneous, or is
readjustment, accompanied by hesitation, focusing of a
and a certain amount of volitional guidance necessary
point of transition from one individual to the next?
any tendency to stop and reverse the sequence at any po

7. Did any associations present themselves? If so,
come immediately and spontaneously, or after an inte
as a result of conscious effort?

8. Do you note any peculiarity of mood?

9. Are you conscious of any movements and of an
sensations?

10. Do you note the presence of organic sensations?

11. Is the process pleasant or unpleasant?

12. Do any clinching or rejecting movements appear

13. How does your attention act? Do you glance at
terial and drop it, turning your mind to other things, or
attention held suspended, involving a continuation of
aesthetic factors present? Do you stop to look over det
try to see what ideas you can bring into connection w
content?

14. Did you have a visual image, either of this pair o
other pairs or individuals? Was it good, clear cut and
Did it come immediately? Was it relatively permanent
ing? Was it stable, *i.e.,* did it hold together in space,
there any tendency toward disintegration.

15. Were there any logical reasons for your judgm
belief that this pair in the natural course of events wa
to be changed, etc.?

16. Was your attention especially called to either in
or was it equally divided between them?

Subjects. The persons serving as subjects in this expe
work were Doctors Hayes (H.), Fernald (Fe.), Vince
and Sutherland (S.); Messrs. Ferris (F.), Jones (J.)
(P.), Beanblossom (B.), Carter (C.), Wylie (Wy.),
(L.), Bickel (Bi.), Johnson (Jo.), Kjerstadt (Kj.),

students specializing in psychology; Misses Abbott (A.), Waterhouse (W.), Ford (Fo.), of whom the first two were graduate students, the latter an undergraduate who had had psychological training.

(2) Quantitative Results

We find that our quantitative results vary from individual to individual and also that the returns in the unknown series are different from those in the known.

Known Series. In computing the number of correct and incorrect judgments, we were confronted with a difficulty. It is perfectly obvious in the case of a change in order or of arrangement that there is only one possible unit and that is the pair. But in the case of the introduction of new individuals, we are dealing with a slightly different situation. There are two individuals in each pair, each of which must be the subject of a judgment. There are accordingly chances not only of assigning a pair containing a new member to the past in all its entirety, and of judging an old pair to contain a new member, but even where the subject judges that he is dealing with an altered situation he may be wrong about the locus of the alteration. He may judge an old individual to be new or a new individual to be old without affecting the validity of his judgment as far as the pair as a whole is concerned. If, for instance, in the case of a pair of two new individuals, the subject should declare one to be new but the other to have been present in the former series, we would, if we were dealing with the pair as a unit, have to count this as a correct judgment of novelty, inasmuch as there is no question that the pair is new. It is obvious, of course, that this would be representing but a part of the truth of the matter.

In order to avoid this difficulty, we adopted the following method of scoring. In the case of changes of order and of arrangement where there is really only one judgment involved in every case, we counted each pair as a unit. In the case of changing individuals, we used the same system where the pair was *correctly* accepted or rejected as a *whole*, since in this case also we have practically a total reaction. In cases where there were

two distinct judgments, *i.e.*, where each individual either did or should receive separate treatment, we counted the individuals as units. There may be some objections to this method, but it was the most feasible that suggested itself in view of the fact that we wished to compare the results of the known and unknown series. The latter introduced difficulties which would make any fair comparison impossible on any other system of scoring that suggested itself. We shall speak of this matter again in considering the unknown series.

TABLE I

Subject	*Possible* *Old*	*New*	*Old judged old*	*New judged new*
B	21	26	80%	57%
J	9	8	67%	50%
F	31	35	77%	83%
Fe	11	12	91%	75%
H	11	13	100%	84%
Fo	16	21	62%	81%
P	12	18	92%	77%
W	17	23	82%	83%

TABLE II

Subject	*Total actual No. judgments of* *Old*	*New*	*Of these, correct* *Old*	*New*	*Percentage of all judgments correct*
B	28	19	60%	79%	67%
J	10	7	60%	57%	58%
F	30	36	80%	80%	80%
Fe	13	10	77%	90%	82%
H	13	11	84%	100%	92%
Fo	14	23	71%	74%	73%
P	15	15	73%	93%	83%
W	18	22	78%	86%	82%

The unequal number of judgments for the different subjects was due to the fact that not all of them worked with series containing all the different alterations. The unequal number of possible old and new judgments in the results of any one subject was due to the fact that in very few cases was the whole of the series of six pairs presented the second time. As the old and the new pairs were not arranged alternately, more of one kind than of the other were presented under these conditions.

Table I represents the relative chance of any content, old or new, being judged correctly. It answers the question, what likelihood is there that an old relation will be judged old as compared with the chances of a new relation's being judged new?

In Table II, on the other hand, we are interested in seeing what the chance is that any specific judgment which is rendered will be correct. The question here is, granted that I have returned an old judgment, how do the chances that it is correct compare with those of any given judgment of novelty? We note then the following:

1. Table I shows us that we are dealing with a matter which varied with the individual, and that no universal statement can be made. Five subjects (B., J., Fe., H., P.) were more likely to judge old content old than new, new; two (F., Fo.) were more likely to judge new content new than old, old; in the case of W. there is no difference. It is then obvious that in the majority of cases old content is more likely to be recognized and accepted as such, than new content is to be rejected.

2. Although the relative reliability of the judgments is also liable to individual fluctuations, still it is clear that wherever any difference exists, the new judgments are the more reliable (Table II). This is true in the case of five subjects (B., Fe., H., W., P.). With the other three subjects no difference is discernible. These results mean, of course, that many new units are erroneously accepted, while but few old objects are rejected. As we noted, the first table indicated that this was the general rule. This result fits in with the old statement that we tend in general to accept things that we have no reason to doubt. It should not be forgotten, however, that this is not absolutely universal, but that the factor of individual variability is always present.

(Unknown Series.)—Where the subject did not know what the alteration would be, the situation is slightly different. Under these conditions every pair raises three questions: (1) Are these the same individuals, (2) Were they together, (3) If so, were they in the same order? It is obvious that there are four possible judgments in regard to every group, one for each individual, one for the arrangement and one for the order. As a matter of fact, however, only a limited number of pairs ever have all the decisions made concerning them. If one of the individuals is rejected, there is nothing more to be said, as the other problems

are simply non-existent. In such cases then, the unit of judgment is really the individual. Where, however, the group is judged to be entirely old, the unit of judgment has been the individuals, but it has also been the group. In order to bring anything like a fair standard out of this, we shall adopt the following rule. Wherever the group is judged entirely old or entirely new, or where it was judged that there was an alteration of order or of arrangement, *provided these judgments did not overlook a difference in the true status of the individuals,* we shall consider the group as the unit. Where, however, there either was or should have been a difference made between the individuals of a group, one being judged old and the other new, we shall consider the individual to be the unit. It will be remembered that we adopted the same system of scoring in the case of the known series in anticipation of the present considerations.

TABLE III

Subject	*Possible* Old	*Possible* New	*Old judged old*	*New judged new*
B	17	14	53%	71%
J	21	8	62%	88%
F	34	25	64%	80%
Fe	13	10	75%	80%
H	18	6	88%	66%
Fo	18	12	83%	75%
P	36	16	44%	81·%
W	24	21	54%	76%

TABLE IV

Subject	*Total actual No. judgments of* Old	*Total actual No. judgments of* New	*Of these, correct* Old	*Of these, correct* New	*Percentage of all judgments correct*
B	13	18	69%	55%	64%
J	14	15	53%	46%	69%
F	27	32	81%	62%	71%
Fe	11	12	72%	83%	78%
Fo	16	14	81%	64%	73%
P	19	33	84%	39%	55%
W	18	27	72%	59%	64%

In the case of subject H, the discrepancy between the number of judgments of old and of new was so great as to make comparison useless.

Turning to Table III it will be noted that only one subject (F.) gave the same results in the unknown and in the known series. All subjects who, in the known series, gave results to the effect that the old content is more likely to be judged old,

now give the opposite relation. Fo. is the only subject for whom old judgments are more likely to be judged old.

It thus appears not only that a difference in the instructions produces a decided change in the complexion of the results, but also that in the overwhelming majority of cases, where the subject does not know what alteration will be introduced, new content is more likely to be judged new than old old. This change denotes in general a greater wariness when the alteration is unknown, the subject not being willing to accept content so readily as old. As we have under these conditions circumstances that approach the way we are operating in normal life, we must regard the unknown series as giving us more insight into the usual workings of the recognitive process than does the known, and we may say that the general law is that no content is recognized as old unless it can show good reasons for such a reception.

Turning now to Table IV we find that, corresponding to the results just noted, for six of the seven subjects, the old judgments were the more reliable. Fe is the only exception to this rule This result is of course directly opposed to what we found in the known series. We will see that these results are correlated with certain peculiarities in the introspective reports which will be noted later.

(3) Surety of Judgment

In all the following sections, the unit, in series with a change of order or of arrangement, is the group; in the series with a change of individuals, it is the individual.

We divided the judgments into two classes; those which the subject reported to be characterized by a relatively great degree of certainty and those in which more or less doubt and questioning was present. It is obvious that there is absolutely no way to avoid a certain amount of arbitrariness in classifying. In the first place, there are a larger number of qualifying adjectives that the subject may use which make it difficult to classify many judgments. Then in reading the reports there is always the difficulty that the same judgments get very different meanings in different contexts. Thus, for example, a judgment of "pretty sure" may mean a relatively great amount of cer-

tainty, as when the subject means, "Yes, I am pretty su that," or it may mean that there is considerable doubt, as the tone of voice indicates that he is, after all, *only* pretty Efforts to overcome this by care in taking introspections but little avail in a large number of cases.

The reports in respect to this matter show that the vary with the different individuals and with the di instructions.

TABLE V. KNOWN SERIES

Subject	*Percentage of Old Judgments plus surety*			*Percentage of New Jud plus surety*	
	Order	*Arrangement*	*Individuals*	*Order*	*Arrangement*
B	68%	75%	57%	60%	17%
J	40%			28%	
F	70%	00%	53%	39%	70%
Fe	87%			50%	
H	80%			62%	
Fo		00%	60%		41%
P		33%	36%		38%
W		91%	64%		50%

The percentage of sure judgments shows large variation individual to individual. Six subjects (P., J., F., Fe., W H.) report as a general rule that the greater percentage o old judgments than of their new are accompanied by sub certainty; one (P.) reports the opposite relation; and f (Fo.) there is no difference. It should be noted here th percentages vary with the different relations that are ch No general rule can, however, be laid down in regard to alteration produces the greatest number of sure judgments may say, however, that, in the large, the majority of the s are more sure of their old judgments.

TABLE VI. UNKNOWN SERIES

Subject	*Percentage of Old Judgments plus surety*	*Percentage of New Ju plus surety*	
		Order	*Arrangements*
B	92%	75%	67%
J	64%	33%	
F	51%	00%	22%
Fe	40%	27%	
Fo	50%		60%
P	53%		50%
W	64%		75%

Again, we find that a change in the instructions prod decided change in the percentage of sure judgments of a

type returned by most of the subjects. On the other hand, there is an unaccustomed unanimity among the different subjects. Five of the seven found that a greater percentage of their old than of their new judgments was rendered with surety, and for the other two (Fo. and W.) there is no difference. In general the same relation appeared in the known series; but the results are much more uniform here, and in no case was a subject found to return a greater percentage in the case of new judgments. We shall show later on that this is correlated with certain peculiarities of the introspective evidence.

(4) Time of Judgments

The decisions were classified on the basis of whether they were reported prior to the closing of the shutter (5 sec.), *i.e.*, while the stimulus was still perceptually present, or were the result of deliberation lasting until after the shutter was closed. Again we are dealing with results that vary with the individual and with the instructions.

Table VII. Known Series

Subject	*Percentage of Old Judgments while Open.*			*Percentage of New Judgments*		
	Order	*Arrangements*	*Individuals*	*Order*	*Arrangements*	*Indiv.*
B	23%	75%	71%	40%	17%	25%
F	70%	60%	77%	39%	75%	100%
Fe	87%			83%		
Fo		100%	100%		75%	100%
P		100%	90%		85%	57%
W		75%	42%		100%	57%

We are unable to find any predominant tendency. In the case of three subjects (B., Fo., and P.) more old than new judgments are returned in five seconds; the reverse relation holds for F. and W.; and Fe. shows no difference. Also the proportion varies with the different alterations, but no rule can be laid down.

Table VIII. Unknown Series

Subjects	*Percent of old judgments while open*	*Percent New Order*	*Percent New Arrangement*	*Percent New Individuals*
B	50%	50%	33%	29%
J	55%	57%		
F	80%	50%	22%	62%
Fe	100%	100%	(based on 8 and 7 judgments, respectively)	
Fo	62%		80%	89%
P	88%		86%	87%
W	76%		83%	79%

With the exception of B., F., and W., the results change w
instructions. Moreover, no general law can be laid dowr
vidual variations playing too large a rôle.

If we consider the matter from the point of view of w
the judgment is rendered before the closing of the shutter
per cent of the cases or better, we get the following results

Known Series

Fifty per cent or more of the old judgments returned
seconds.....five subjects. (B. not.)

Fifty per cent or more of the new judgments retur
five seconds.....five subjects. (W. not.)

Unknown Series.

Fifty per cent or more of the old judgments returned
seconds.....six subjects. (B. not.)

Fifty per cent or more of the new judgments retur
five seconds.....five subjects. (B. and F. not.)

It thus appears that for the majority of the subje
judgments of all classes were returned before the per
content was removed. This was not so in the case of
other subjects conformed to the rule except in a few in
with one type of judgment.

(5) Unitary Character of the Percept

There are two possible patterns of attention. The
may apprehend the group as a whole, *i.e.*, it may form fo
perceptual unit, or he may apprehend and attend to the inc
members of the group in sequence. Under the latter co
one individual fades into the fringe when the other is
focus. An attempt to see whether these differences in the
of the attention form the basis for distinguishing betwe
tent judged old and that judged new led us to a negative
No correlation between any particular mode of functio
the attention and any particular cognitive distinction c
shown to exist.

There is a certain amount of individual variation a
instructions and the particular alteration have an effec

subject B. the rule is that all groups are apprehended as a whole. For F., W. and H., there are cases of both kinds of process, with both kinds of judgments. In the case of Fe., the groups are as a general rule split up under all conditions. With J., and Fo., the old groups are predominantly taken as units, while the new ones are separated into their constituent parts. With P., the matter varies with the instructions. Where the alteration is known, both types of judgments are accompanied by the dissociating tendencies, while in the unknown series, the old groups are dealt with in both ways. In the case of Fo., where the judgment was returned that the alteration was one of arrangement, a group was always reported as being composed of two relatively individualized units. This is the nearest approach that we have to anything like a correlation between a peculiar pattern of attention and a particular judgment. It holds good only in the case of one type of alteration. As, however, old groups also were perceived in the same manner on occasion, this gives no basis for differentiation.

(6) Distribution of Judgments

In the unknown series, not only are altered groups judged old and unaltered new, but the subject may err also in stating exactly what change has taken place, although he is sure that some sort of rearrangement is present. This happened with practically all subjects, and is of interest as indicating that novelty will make itself felt even when the subject is unable to specify the kind of alteration introduced.

(7) Mood

In the reports recorded under this head, we did not include the cases where the feeling of familiarity was reported. It was the intention of the experimenter to take up the matter later under conditions which would allow of a better chance for analysis. At present it seemed that, lacking such analysis, it was not possible to tell whether when a feeling of familiarity was reported, the subject really was referring to a phase of the content of the experience or was merely indicating that he was

conscious that he had seen the pair before. To avoid
prehension, however, it might be well to say that with
exceptions, a feeling of familiarity was never mentioned.
was especially noticeable in the case of subject P., a
observer, who reiterated over and over again that no suc
ing ever appeared as far as he could determine, but tha
was present was a consciousness of reference.

TABLE IX. KNOWN SERIES

Subject	*Order*		*Arrangement*		*Individ*
	Old	*New*	*Old*	*New*	*Old*
B	53%	80%	50%	67%	57%
J	50%	57%			
F	23%	07%	00%	20%	00%
Fe	08%	30%			
H	00%	27%			
Fo			00%	50%	46%
P			33%	37%	08%
W			75%	100%	42%

TABLE X. UNKNOWN SERIES

Subject	*Old*	*New Order*	*New Arrangement*	*New In*
B	33%	50%	78%	86
J	64%	73% (all new)		
F	03%	17%	50%	74
Fe	09%	27% (all new)		
H	17%	00% (all new)		
Fo	19%	21% (all new)		
P	10%	12% (all new)		
W	07%	11% (all new)		

In the unknown series, with the subjects who did no
to series where all three alterations had been made, w
indicated the percentage of *all* new judgments accompa
moods and have not made separate computations for the
ent alterations.

It will be noted that in the majority of cases no mood
soever was detected by the subject as accompanying his r
Nevertheless there were a number of moods which wh
did appear were peculiar to specific judgments. Thus
that the following were reported with old content at d
times and never with the new units:—comfort (5 cases
security (10), ease (2), lack of ease (1), restlessness (
tainty (3). The following were peculiar to the new con
interest (3), wonder (1), disappointment (1), inquisit

(3), coldness and remoteness (1), a feeling of being baffled (1), feeling of being at rest (1). Moods common to both were: curiosity (32), annoyance (8), satisfaction (22), discomfort (3), surprise (24), amusement (4), strangeness (3), dissatisfaction (4). The numbers in the parentheses indicate how many times any specific mood appeared in the course of the whole experiment.

While they are by no means necessary and inevitable accompaniments of the judgments, there appear to be certain moods which are present with one type of judgment only. As such they must be classed as criteria, as when they are present a specific reaction invariably takes place. We emphasize again that the evidence here presented overlooks for the time being the question of a feeling of familiarity. We have, however, already given reasons why we consider that this (if it exist at all) is a relatively rare phenomenon. Lastly we note that the mood correlated with novelty is not surprise as was alleged by Perky. On the contrary, we find that surprise occurs with either type of judgment.

Affective Tone.

TABLE XI. KNOWN

Subject	*Percent Pleasant*		*Percent Unpleasant*	
	Old	*New*	*Old*	*New*
B	68%	10%	14%	35%
J	10%	14%	00%	14%
F	03%	09%	07%	09%
Fe	39%	30%	08%	00%
H	00%	27%	00%	00%
Fo	36%	22%	14%	14%
P	40%	13%	07%	20%
W	11%	14%	28%	19%

TABLE XIII. UNKNOWN SERIES

Subject	*Percent Pleasant*		*Percent Unpleasant*	
	Old	*New*	*Old*	*New*
B	54%	15%	11%	27%
J	21%	07%	00%	00%
F	03%	09%	07%	06%
Fe	46%	40%	07%	00%
H	33%	17%	17%	00%
Fo	06%	07%	12%	14%
P	16%	12%	05%	12%
W	07%	11%	07%	00%

We note here, in the first place, that the great majority of

all judgments were neutrally toned. In the second place
is no correlation between any particular tone and any pa
judgment. This is directly contrary to the doctrines enu
by both Titchener and Külpe. It should also be noted t
results vary from individual to individual, and also with i
tions. It is probable, however, that this is a pure ma
chance, inasmuch as the cases are so few in number, whe
affective tone at all was recorded.

(8) Motor Phenomena

There were certain motor phenomena the appearance of
were noted only with particular judgments.

1. A feeling of right-and left-handedness. In the c
B we noted that there was a right- and left-handed attitu
accrued to each individual of a pair in virtue of its pres
uation. With him this does not seem ever to have se
influence the judgment, as it was a mere accompaniment
present situation, a right-handed feeling always occurrin
a present right-handed individual even though the posit
cupied was judged to constitute an alteration. There
other words, a correlation between the feeling and the
situation, but none between the former and the old co
expressed in the judgments. With J, however, the phen
was of real value in guiding his judgments. We believe
are here dealing with a criterion, as there is a correlation
the specific attitude and the judgment returned concern
former situation. Twice J. said that immediately on the
ance of the stimulus, there was a feeling of strain with
the individuals in the opposite arm and shoulder. Both
J judged that the order had been reversed; both judgmen
correct. In a third instance there was a correspondingl
ized feeling of strain with each of the figures that co
their positions on the sides on which they appeared. Th
ment was also correct. It appears, then, that althou
phenomenon was relatively rare, it actually served to gui
his reactions on occasion.

2. General motor clinch. With B., we have another

phenomenon which is of much more significance. In a number of cases, where individuals or whole groups were judged old, B. spoke of a tendency to get out towards the recognized units. This occurred, even in instances where the order or arrangement was judged changed. It is, then, a criterion, not of the fact that the whole complex is unaltered, but that the elements composing it were the same. Also, in the unknown series, in 57 per cent of the cases where the individuals were judged to have been altered, B. said that he was conscious of a movement of withdrawal. Here, of course, we have concomitant variation, a particular type of motor phenomenon being correlated with a particular type of judgment. And this, as we said in the beginning, is the sole basis on which we can hope to establish structuralistic criteria. J. also reported much the same thing. Here, we have no evidence of what might be called the negative clinch, but on the other hand, with old content, J. spoke of a tightening of the muscles of the neck and shoulders, a sort of general affirmative kinaesthesis. There was only one exception to this rule, where with an unfamiliar individual the same thing took place. In this case, however, its appearance was delayed. Aside from this, it occurred nine times in all. In the records of H. also, in one instance where a pair was judged completely unchanged, we find mention of a forward movement of the whole body at the time of recognition.

3. Miscellaneous. In two cases, J. spoke of a tendency to outline a geometric form, and judged the individuals to be old. The judgments were correct. Fo. reported in one instance a feeling of lack of muscular balance where the arrangement had been altered, and on a second occasion spoke of an attitude of outlining a triangle, which led to its acceptance as an old figure. Both of these judgments were correct.

All other subjects reported that no such phenomenon was ever present. We see, then, that the criteria used in differentiating old and new content are different for different individuals. This fact is of great importance. No theory of recognition has ever succeeded in bringing forward clear proof of its validity and

they have all tended to assume that the differentium of the recognitive process lies in one or two factors which are common to all individuals. As subsequent experimentation did not find these factors present with some individuals, the theories were rejected. Nevertheless they may have been correct in depicting what lies at the basis of recognition for some people. The fact that given criteria are not universally in evidence, does not prove that they are not criteria in some instances.

(9) Action of the Attention

It is conceivable that there may be two distinct ways in which the attention acts. In the first place, the subject may look at the stimulus, apprehend it instantaneously, and relax his attention or let it slide over to something else. In the second place, the attention may be strongly called to the presented situation, may be "snagged," so to speak, on the content, and this may involve a long period of effort and manipulation. We have already noted previously that Meumann posits the first as the pattern of the attentive process in the case where the subject is dealing with old content. We, however, were unable to find any sort of concomitant variation, except in one case. The attention may be immediately relaxed and turned to something else, or it may be prolonged, involving kinaesthetic strain, an effort to manipulate the existing situation, with stimuli judged old, or with those judged new. For J. in the unknown series, we find that the latter pattern is the only one present with new content. On the other hand, it also occurs with old content, and the correlation is far from universal. Still it may be said that there is a tendency for new stimuli to hold the attention. This can hardly be looked upon as a criterion, however, as there is no general one-to-one relationship.

(10) Visual Images

Visual images forms another great class of criteria. Once again, at this point, we call attention to the fact that it is not the subject's judgment that he is utilizing an image as a means of formulating his decision that we are relying upon,

as we have already pointed out that he may not know to what he is reacting or that he may be entirely mistaken in the matter. The results given here are rather based on a careful examination of the introspections, which shows that certain peculiarities of the images are only present with a particular judgment. This is, of course, as far as experimental psychology can go in establishing a casual sequence. Certain phenomena occur only with certain others. This does not mean that they are always present, but that there are no cases in which they are found correlated with a different meaning distinction. Moreover, the subject's introspection as to whether an image came before or after the judgment cannot be anything but unreliable, except in very extreme cases. Because of this, we will as a general rule omit all reference to the time order, and turn our attention purely to the fact of conmomitant variation. We found that the following peculiarities of visual images were correlated with differences in meaning:—

1. *Mere appearance.* With certain subjects, in both series and with others in the known series only, the mere appearance of visual images of the presented content or of intimate associates leads to judgments being returned in accordance with their dictates. This would mean that individuals arousing visual images are accepted, while those failing to do so (provided, of course, no other criteria, such as associations, are present) are rejected. Where it is a matter of new arrangement or order, the content of the image will settle the question. Thus, in the first case, the appearance of one of the individuals presented in the stimulus with a different partner from that accompanying it at present will lead to the judgment that there has been an alteration of arrangement introduced; and the appearance of the presented individuals in an order different from that given will lead to a judgment that the latter has been changed.

The subjects using this criterion are J., F., Fe., and P. and W. in the known series. We will give in a table (No. XIII) below, the number of cases in which an adequate visual image was present, the number of cases in which the subsequent judgments

were correct, and the number of cases which formed exceptions to the rule, *i.e.*, where the judgment was not in accordance with the dictates of the image. We will consider the latter further on in detail. It should be clearly understood what we mean by an adequate visual image. Where the subject, for instance, knows that the only alteration will be one of order, the appearance of an image of an isolated individual is of no value to him. He already knows that no new individuals will be introduced. An adequate image under these conditions is one which has sufficient import to serve as a clue to the solution of the problem in hand, *viz.*, whether the order has been altered or not. It is of course obvious that in the unknown series no visual image is ever inadequate, as in this case the subject is in need of light on all matters.

TABLE XIII

Subject	*No. of Cases*	*No. of these correct*	*Exceptions*
J	8	7	2
Fe	11	11	1
F	20	18	5
P (Known Ser.)	8	7	0
W " "	22	20	1

Four of the exceptions appeared where the image was so vague and fleeting that the subject was unable to say confidently whether it had existed or not, and was in even a worse position in respect to his ability to describe the content. We can say, then, that too great a degree of vagueness and schematic character will vitiate any claims the image may have as a valid criterion. The other five exceptions were as follows. Four of them were in the case of F. Three were cases in which conflicts between two different images took place and we will consider them later. The fourth will be taken up under the subject of manipulation. The last exception was reported by W. Here shades of the same color appeared in two successive pairs, and the result was the arousal of so large a number of images of different tints and hues that the subject was unable to come to any conclusion and rejected the individuals.

2. *Stability.*—In this case, where the image of the presented percept is stable and does not tend to fall apart in space, the

content that it represents is accepted as a duplicate of the past, while instability leads to a judgment of novelty. The subjects using this means of differentiation were B., Fo. in the case of known arrangement, and W. in the unknown series. It appears then that the criteria used not only vary with the individuals and the instructions, but also with the particular alteration involved.

TABLE XIV

Subject	*No. of Cases*	*No. of these correct*	*Exceptions*
B	42	30	7
Fo (Known Arr.)	9	7	0
W (Known)	2	0	0

B.'s results are most interesting in this connection. There seems even to have been a certain amount of correlation between particular types of instability in space and particular changes in the group. In the case of changed order, the instability may be of a very incipient character. We find B saying that when he attended to the visual image of one of the two individuals, the image of the other tended to fall off into the fringe: or it may happen that the image which came initially as the copy of the presented situation would suddenly experience a transformation and one individual would move over to the other side of the second. Again one individual would move up and away in space. When the arrangement was judged changed, B. reported that one individual moved off and down in space, while a new one tended to move back from the other. The correlation is not universal, but is striking enough to be significant. Of the exceptions in the case of B., two are due to the fact that the records are not clear on the points in question. Three other cases were visual images of content associated with the groups, and led to old judgments. In the last two instances, the image was rejected because of a negative motor reaction in the one and of a delayed associate in the other.

3. *Locus in Space.*—Two subjects used this as a means of differentiating the two kinds of content. For Fo., whatever placed itself on the side of the drum where the initial pair had been presented was accepted and the content that it represented was

judged old; whatever appeared on the new side was jud (except in the instances where it was known that the ment was changed, for which see stability above. Here made no difference). H. also employed this method in d ing whether or not a specific individual had been on the which it was re-presented. We have here an instance the subject was keenly conscious of the correlation b phase of the content and her judgments. When an ima individual placed itself over the percept that correspond the order was judged unaltered, but if it placed itself other individual a change was judged to have taken pla

TABLE XV

Subject	*No. of Cases*	*No. of these correct*
Fo	31	26
H	4	4

One exception with Fo. is due to the incompletenes record. Two others were cases where the images of failed to show all the digits and hence they were reje the last instance, an association overcame the testimon image. The exception reported by H. is due to in records.

4. *Image of a Pair Containing on Individual not Prese Percept.*—Where an image came up composed of one i present in the percept and one not so given, some subject that there had been an alteration of arrangement, rega the stability of the image. These subjects were Fo. (k rangement) and W. in the unknown series.

TABLE XVI

Subject	*No. of cases*	*No. of these correct*
Fo	4	4
W	7	7

The one exception reported by W. appeared where t was so vague that the record gives no further details ing it.

5. *Quality.*—In the unknown series, P. accepted a images which represented pairs which differed from th

in the percept. Associated images were also accepted. All images of the perceptual content itself were simply regarded as useless, being compatible with either judgment. This is easily understood from a logical point of view. The image of the present content is likely to be aroused by the stimulus, and hence may owe its appearance to the present situation. The image of content other than that presented in the percept has no such grounds for existence. There were three instances in which the image did not correspond to the percept. The judgments of novelty were all correct.

6. *Immediacy.*—In the unknown series, W. accepted as criteria images which represented the presented content, provided they came immediately. (Stability and Immediacy vary concomitantly. See Stability.) Otherwise the image was compatible with either judgment. There were ten cases where images of pairs and individuals presented in the stimulus came immediately, and in eight of them the judgments were correct. In seven cases, the image was delayed. In five of these instances, the content was judged in a different way from the implication of the image; in the other two, in accord with it.

8. *Failure to submit to manipulation.*—In one case F. tried to place the visual image of a pair on the side of the drum where the initial series had been presented. One individual took up its place there and stayed. The other would not. This led to judgments of old and new respectively. Both judgments were correct.

9. *Mode of Entrance.*—Fo. judged the arrangement to be new when the presented pair came in piecemeal, *i.e.*, one individual trailing in after another. In contrast with this, we find that the old judgments were correlated with images that came in as a whole. There were seven such instances of succession in appearance. All the judgments were correct.

10. *Conflicts.*—Conflicting images were frequently met. We find that under these conditions, the more permanent, *i.e.*, the image that is less fleeting, or the more stable, *i.e.*, the one which coheres best in space (F.), or the more assertive, that which keeps

tending to reappear in the focus of attention irrespective of the desire of the subject (W.), is the one which is accepted.

We note in summarizing, that the criteria employed, even within the sphere of visual images, differ from individual to individual. Moreover, the difference in instruction (known vs. unknown series) is a decisive factor. Thus W. accepts all images in the known series, while in the unknown, she accepts only the stable or the immediate. Moreover, differences in the particular alteration introduced cause a fluctuation in the particular criteria employed. Thus Fo. normally relied on locus in space; but in the case of known arrangement, accepted *any* pair containing an individual not present in the percept, and rejected the unstable and those that came in piecemeal.

In the next place, we note that all the peculiarities are such as can be readily subsumed under the concept of habit. Appearance vs. lack of appearance of images (effectiveness for central excitation, ability to arouse concrete activities), stability vs. instability, location in an old place vs. location in a new, immediacy vs. delay, etc., are all of them antitheses which from a psychological point of view may be considered as representing two poles in a content where the relationships of the elements have been altered.

Moreover, we note that in a number of instances which constitute a small proportion (16 per cent), it is true, of the total, the criteria are correlated with incorrect judgments. This is, we believe, no evidence against their validity as being the basis of the decision. It is, of course, well known that we are constantly subject to error in regard to the matters in question, and the fact that we find here certain reasons which can be given for this incorrect classification is rather a point for than against the whole doctrine. This also seems to make it intelligible why the *exceptions* occur. The subject in his own experience has found that his criteria are not absolute, and hence regards them more or less askance. Consequently on occasion, he will defy their authority and judge in ways which are not in accord with their dictates. Sometimes he gains by this, but sometimes he loses.

In conclusion, we note that wherever the criteria used differ

from the known to the unknown series, the alteration is one which shows that under the latter conditions the subject is more wary about giving credence to any content. Thus in the case of P., for instance, we find that all visual images are accepted as criteria in the known series, while in the unknown series, only images which represent pairs other than those given in the percept are utilized. W. shows much the same type of change, as can be seen from the above. We may say, then, that the more indefinite the problem and the greater the chance of error, the more specifications the subject lays down which the image must fulfill for acceptance.

This latter peculiarity makes it easy to explain the alteration in the relative reliability of old and new judgments from the known to the unknown series. We found that in contrast to the conditions existing in the known series, in the unknown series the old judgments are more reliable. This fits in nicely with the results of the last paragraph. For where more requirements are laid down which the criteria must meet if judgments of oldness are to be returned, we would naturally expect these judgments to be more often correct. On the other hand, this increased care naturally adds to the number of instances in which old percepts which cannot present clear credentials will be rejected, a proceeding which undermines the reliability of the new judgments. Thus our introspective and our quantitative results fit in together, a fact that strengthens the claim of the general doctrine presented.

(11) Associations

In the case of associations, also, we find that there is a variation from individual to individual, and from series to series. No difference can be observed with the various alterations, however.

The question of the adequacy of any association has to be taken into account, if we are to look upon it as a content capable of mediating a judgment. We will say that an association is adequate to mediate a decision of familiarity provided (1) it is believed by the subject to come from the past. This does not mean that the subject explicitly judges that it comes from the

past, but that he judges in accord with it (concomitan tion). (2) The second condition is that an association sufficient, *i.e.;* there must be enough in its content to med particular judgment made. Suppose that I have the nonsense syllables "mon fif," and that I have formed sociation, "man blowing a fife," with them. Now, on re tation of the new series, the order given is "fif mon." association is, however, resurrected and considered to b It is obvious then that the decision that the pair had been would be involved in the association itself as the order words demands a different order of the syllables. Suppos ever, that I had only the associate "man," which returne I saw the pair again. If then under these circumstance decided that the pair had been changed in respect to th of the individuals, I could not attribute the judgment implication of the association, even though I accepted th as having constituted a part of my past experience. Th ciation is insufficient, though believed. It follows fr foregoing discussion that there are three classes of as possible: (1) those which are sufficient and believed, (2 which are insufficient but believed, (3) those which are *i.e.,* are looked upon as products of the present situatio

Omitting, then, all insufficient associations, inasmuch contribute nothing to the results, one way or the other, that the following properties of associations serve to gi the power to mediate judgments, *i.e.,* make them adequ

1. *Accepted as they appear.*—In this case, the judgmen dered in accordance with the implications of the associat mere appearance of which is sufficient to guarantee it considered to come from the past. Its presence will lea acceptance of individuals arousing it, while its absence looked upon as a basis for rejecting individuals, unle criteria are in evidence. Moreover, its meaning, if a will determine the judgment returned in the matter of th and arrangement. (See above illustration.)

The subjects who accepted associations as they came (except the names of geometric figures, q.v.), F. (excep

of colors and geometric forms, q.v.), Fe., H., P. (as J.), and Fo. in the known series. The following table indicates the number of cases where associations mediated the judgment and also the number of exceptions to the rule. The latter comprise the instances where content was judged new in spite of the presence of sufficient associates.

TABLE XVII

Subjects	*No. of cases plus Associations*	*Exceptions*
J	13	0
F	84	3
Fe	30	1
H	32	2
P	35	4
Fo (Known Ser.)	18	3

With F., one of the exceptions is accounted for by the fact that the subject said that he believed that a new individual was about due. As a consequence, he rejected the individual even though it aroused an association. In a second case, the association itself implied the rejection of the individual. With Fe., in one instance, the order of a pair was judged reversed although the presented order aroused a sufficient association. The subject said that the idea was so obvious and so familiar that if she had had the pair before she would unquestionably have had an anticipatory image of it. As no such image was noted, the pair was judged reversed which was correct. One of the exceptions reported by H. is accounted for by the fact that the system which she had worked out in connection with the presented series "would not work." It appears that it was not sufficiently definite to be useful. The other exception falls under the head of conflicts (which see below). Two of the cases reported by P. can be explained by the fact that the associate was, so to speak, implied in the very syllable judged new itself. The attempt was, of course, made to get syllables with a minimum of meaning attached to them. When a subject uses auditory imagery this is not always easy, however. Thus the syllables Yir and Gef suggested "year" and the name "Jef" respectively. The point here seems to be that an associate of this kind, which is, so to speak, inherent in the very syllable itself, is not a guarantee of

oldness. One might say it is too obvious. Fo. rejected three individuals arousing associates. In one of these instances, the judgment was due to a definite visual image. In the second case, the associations aroused were ideas which had been involved in the work with the previous pair, and were hence looked upon with suspicion. The other is a true exception. Taking into account these factors that I have just mentioned, there are of course still a very few (4) bona fide exceptions to the rule.

2. *Immediacy.*—We have already discussed this matter in the case of visual images. The content arousing an associate immediately is judged in accordance with its implication (mere presence being sufficient for the accepting of individuals), while delay in the appearance of the associate leads to the rejection of the pair or stimulus arousing it. The subjects using this criterion are B., W., and F. (in the unknown series).

TABLE XVIII

Subject	*No. of immediate associates accepted*	*Exceptions*
B	21	0
W	29	5
Fo (Unknown Ser.)	14	5

TABLE XIX

Subject	*No. of delayed Associates plus new Judgments*	*Exceptions*
B	2	0
W	10	3
Fo (Unknown Ser.)	4	0

There were six cases where adequate associates were not correlated with any judgment concerning their immediacy. We omitted these from the record therefore. That this was not favorable to our conclusion is obvious from an examination of the introspections, all of which tend to show that the associates were probably immediate.

With W. the correlation is less universal than with the rest of the subjects. A good visual image led to the accepting of the content in one instance in spite of a delayed associate. The other four cases where content arousing delayed associates was accepted are clear exceptions, as are the three where immediate

associates are correlated with new judgments. Three of the exceptions noted with Fo. were due to the presence of visual images.

Quality.—J. and P. regarded the ability to name geometrical forms as being entirely irrelevant, *i.e.*, either judgment may be returned with individuals so named. F.'s reports show the same reaction to the names of colors, and to those of geometric forms in the unknown series.

Contradictions.—We find in two cases of contradictions that F. accepted the first alternative which offered itself, while H. accepted the second. The logic of the second situation seems to be that if anything puts in an appearance as the result of prolonged consideration, the assumption is that there must have been some reason for it, and hence it is looked upon as a valid basis of judgment.

We find that the introspections given by Fo., who used different criteria in the known and the unknown series, bring out the identical peculiarity noted in the consideration of visual images. There is an additional condition laid down which must be met if the content is to be accepted. Mere appearance is no longer adequate, immediacy is also required.

There were among the judgments returned on the basis of these criteria a small number of errors. These are readily understood. The inherent suggestiveness of new pairs may be so great that they arouse associates, and thus lead to judgments of oldness. Moreover, immediacy and delay are relative terms, and the subject may consider (or react to) an associate as delayed when relatively speaking it is not so. In consequence we can readily understand the exceptions of the rule. As appeared when we were studying the visual images, we find that associates lead us into errors in life and we are hence somewhat sceptical as to their absolute validity. As a result they are, on occasion, disregarded. Sometimes the subject gains by this, but sometimes he loses.

These peculiarities are manifestations of the working of the principle of habit. The ability to arouse associates is, of course, a result of irradiation of the nervous excitation over associated

tracts, which would be already worn in the case of an habitual or old stimulus, as connections had been established at the time of the earlier presentation. A new stimulus would fail to find any such pre-established paths, and associates would hence fail to appear. The immediacy and delay of associates would be explicable on the same basis, the impulse needing more time to work over into other brain areas, where the tracts have not been opened up as the result of an earlier presentation. The lack of value attached to the ability to name geometric forms and colors may also be looked upon as the result of the activity of habit. We are so used to giving some sort of a designation to forms and colors, in other words this type of reaction is so thoroughly habitual, that it is altogether intelligible that the subject should not attach any importance to its presence. It is a case of too much habit. The thing is so automatic that there is no guarantee that it has not been done on the spur of the moment.

(12) Organic Sensations

There were practically no instances in which organic sensations were reported with any subject. This does not mean, of course, that careful attention would have failed to discern the ordinary sensations from the body, but that the subjects failed to find that there were any distinct and differentiable complexes.

Fe. was the only subject who stated that the organic background of a new stimulus was different from that of an old one, and this occurred but once. As a goodly proportion of the judgments were not expressive of direct apprehension, since doubt and deliberation were present, this evidence tends to prove that for our subjects at least the feeling of familiarity, analyzable into pleasantness and organic sensations, which Titchener considers to be the prime factor in recognition, was non-existant. Likewise Külpe's theory that direct recognition which does not involve the reproduction of sensations repeating circumstances of the original situation, is due to a mood, which is, of course, for him a complex of organic sensations and affective processes, does not fit in with the results here reported.

(13) Rhythm

H. judged old a pair having a decided rhythmical quality when articulated. This is a peculiar and unique criterion, emphasizing the individual character of the standards used.

(14) Classes of Judgments

We come now to a consideration of the question as to whether the factors enumerated as criteria were universally present when judgments were returned, and if not, whether we can formulate a statement of the general conditions under which they were. In going over the introspective results, we found that there seemed to be in general five classes of judgments which may be distinguished:

1. Cases where the judgments were made immediately in time without the intervention of any observable mediating content, other than the percept itself. In these instances, the subjective certainty is great. It might on occasion happen that an associate would present itself immediately following the decision or that a visual image would appear to confirm the judgment. I have called this class of judgments, characterized by their immediacy (in time), their subjective certainty, and by the lack of any mediating content outside of the *percept itself,* A1. When associates, etc., later put in an appearance, I call it "unrolling of content." These terms are merely for convenience. Judgments of this type constitute 18 per cent of the total number, and 81 per cent of them were correct.

There are two possible explanations of this phenomenon. In the first place it may be that there are criteria (other than the percept) actually present in these cases, but that either our concepts are inadequate to grasp them, or the whole process is so quick and automatic that the subject is not able to isolate them. This possibility must be frankly recognized, and we make the following statements subject always to revision from such a point of view.

On the other hand, we are inclined to a different explanation in the light of the following facts. First, all experimenters have

reported cases where they were unable to isolate anything beyond the mere judgment or meaning of known and unknown or their equivalents (in addition to the percept). Secondly, the judgments grouped under the head *A1* form a definite class, characterized by a specific set of properties. If they are to be explained as being due to the failure to note criteria, we should naturally expect to find them scattered here and there, and lacking any common properties that would group them together. For the failure to note criteria should crop out at irregular intervals, being directly due to fatigue, inattention, practice leading to stereotyped response, distractions, etc. Thirdly, our introspections were as exhaustive as we were able to make them. In view of these facts we are inclined to think that the following explanation is correct.

These are judgments in which the perceptual object itself is the mediating content. As a change in the stimulus may lead to a change in a motor reaction, as we use a different stroke in playing a ball with a different bound in tennis, so a difference in the percept may lead, on its own account, to a varying cognitive classification. A changed stimulus brings with it a judgment of novelty, an unaltered situation results in a judgment of oldness. We are justified in believing that the content which is effective in determining the response is the character of the percept itself, by the fact that there is so great a degree of correlation between the meaning distinctions reported and the actual status of the object. The percentage of correctness is 81 per cent. If there were no guiding factors at all in the situation, if as the exponents of unmediated cognitive distinctions maintain, there is no necessary relation between any phase of the content and the meaning, there should be no pronounced correlation between the two phases. Our figures show that this latter exists, however. In as much, then, as there is obviously a correlation between content and meaning, and as there are no differences in content except those contained in the percept, the latter must be the guiding factor. Moreover the fact that the reaction comes immediately tends to show that the percept itself is the efficient agent. There is no period of doubt, but the mere appearance of the

percept induces the response. This seems to show that the stimulus is sufficient in itself to allow of the cognitive reaction.

It is true, we believe, that no exponent of an unmediated recognitive reaction (such as Höffding) would ever had denied that there was a factual correlation between the stimulus and the meaning. But we object to having this type of judgment called unmediated. For the reasons given above (to which others will be added later) we consider our decision of the A_1 class as truly mediated. But the mediating factor is the percept itself. In conclusion, we note once again the highly interesting fact that the only cases where this particular relationship holds is where the judgments are highly automatic and certain. It practically never occurs that, when there is doubt, the percept alone is adequate to force the decision. Only where the past series has been firmly fixed, where it for some reason made a deep impression on the subject can the latter dispense with all aid except the stimulus.

2. There is another class of judgments in which the decision is sure and immediate in time, but there is also mediating content which comes with it. The two (judgment and content) may be so nearly contemporaneous in their appearance that the subject cannot tell which came first, but the main point is that the content does not come consciously after the decision. This we call class A2. It constitutes 30 per cent of the total number of judgments and 89 per cent of the cases are correct.

3. We come now to the judgments where there is a certain amount of doubt with subsequent conscious decision. In this case, the subject appeals to criteria other than the percept. This does not mean that he is aware of what the criteria are and can isolate them as they come in. What actually happened is that he is not sure of what decision he should return and stops to think. In the course of time he comes to a decision. Just what is the efficient agent in relieving the tension, *he* may or may not be conscious of. The fact is that a careful examination of the introspections indicates that there are certain peculiarities of content which are present only when a specific judgment is returned. Hence these are to be looked upon as the criteria which

have brought about the decision even though the subject does not isolate them as such. We have spoken of these matters before.

These criteria may be positive or negative. Under the head of positive criteria are classed all peculiarities of content such as unstable visual images, delayed associates, etc. These are definite data which can be observed. The decisions reached on the basis of such criteria vary in the degree of subjective certainty accompanying them. The judgments may be looked upon as undoubtedly correct or they may still be regarded with distrust. Such judgments where we have doubt followed by a decision on the basis of *positive* criteria we call class B1 if the final stage is characterized by a high degree of subjective certainty, and B2 if doubt still lingers. They comprise 30 per cent of all the cases and 72 per cent of them are correct.

4. On the other hand, the result of the reflective period may be that no additional content, no images, associations, etc., appear. The percept stands isolated in consciousness. Under these conditions the general rule is that the content is judged new (in 78 per cent of the cases). This lack of associated material and failure to stir up any reaction constitutes what we have called a negative criterion. The resulting new judgments are generally (81 per cent) returned with more or less misgiving. They are also very unreliable, only 44 per cent of them being correct.

From these data a number of interesting conclusions follow. In the first place, the objection might be made that we are not here dealing with mediated judgments at all, that our so-called cases with negative criteria, are really instances where the ultimate unmediated consciousness of novelty is in evidence. This is refuted by the fact that in 78 per cent of the cases where no decision was reached immediately and surely on the presentation of the stimulus (A1 and A2), where *i.e.,* a period of doubt was observed, and where no positive factors appeared to settle the difficulty, the content was judged new. There were, if anything, more old stimuli than new. If then an unmediated consciousness of status lies at the basis of these decisions, they should be approximately evenly distributed between classifications as old and

as new. But that in the great majority of instances novelty is declared for, proves that the absence of a positive criterion is itself a ground for judgment.

In the second place we see that the negative criteria are thoroughly unreliable, only 44 per cent of the judgments being correct. This is very strong additional proof that in the A_1 decisions the meaning is mediated by the perceptual content. In the instances now under discussion which we will classify as C, the percept is unable to arouse a definite reaction. The judgment does not come immediately (in time) and surely, but there is a period of hesitation and delay. This is not followed by the appearance of positive criteria. Here if anywhere we should have unmediated judgments. We have found, though, that the subject will then use something (lack of reactions) no matter how unreliable as a criterion. It is impossible for the subject to dispense with some basis for his decision other than internal inclination (if we except a guess here and there). Moreover, the absence of positive criteria leads to highly fallacious answers, a fact which marks off these C judgments from those classed under A_1. The latter must then have some true objective guiding principle (*i.e.* something besides an internal impulse or unmediated inclination) and the only content capable of furnishing this is the percept. The C judgments comprised 15 per cent of all.

We conclude then, that in some cases the percept itself can carry the meaning. These decisions are characterized by coming immediately, by the great confidence felt by the subject in his answer, and by a high degree of correctness. Where there is doubt, either positive criteria, or negative criteria are invoked. Unmediated decisions are rare.

5. It sometimes occurred that, in spite of the absence of any positive criteria, the content was judged old where the percept did not mediate the decision, doubt being present at first. There were in all sixty-four such cases where the subject judged the content old in spite of the absence of positive criteria. Half of them can, however, be accounted for on the basis of suggestion. They occur in the unknown series. Here there are four judgments which can be returned concerning any pair, as has been

pointed out. Now let us suppose that the individuals and the arrangement of a pair are classed as old due to an association, which however contains no reference to the order. It is more than likely, then, that if the order is judged old and the judgment belongs to this last class which we call D, the decision may be a carrying over of the tendency to accept the content which owes its origin to the association mentioned. In fact this seems to have been the real explanation of these judgments. The subject being assured of the oldness of most of the situation, merely accepts the rest without specific questioning. This eliminates thirty-two of the sixty-four judgments of the type D from any further consideration. These are not counted in the percentages.

There remain, then, thirty-two judgments of the type under discussion. Part of these again really do not belong under the D class. Since in the unknown series only one relation is altered at a time, the subject is aware that if he has once isolated the new aspect, he is justified in returning old judgments concerning all the rest. Such judgments are really reasoned conclusions. There remain, then, those cases in the unknown series where the pair as a whole was judged old without any criteria being involved, and those where one individual was judged old and the other new. To these must be added all the instances found in the known series. From these sources we obtain in all twenty-five judgments of the type D, of which 72 per cent were correct.

There are two possible interpretations of these twenty-five D judgments. On the one hand it may be claimed that they, together with the judgments of novelty on the basis of negative criteria, represent the true recognitive reaction, and that the so-called reflective stage is a later development, and is actually superfluous. The real cause of the judgments of both types is an ultimate unanalyzable consciousness of reference, which is clearly observable in the D and C decisions. The preponderance of classifications as new, referred to earlier, can easily be explained if we assume that only content which makes a fairly strong impression when presented, can arouse the meaning of oldness. If then, in addition to the truly novel stimuli, we thus have all percepts which made but little impression cognized as new, we can see why the

judgments of novelty predominate. This hypothesis seems to receive some substantiation from the fact that the subjects spoke in quite a few instances of an immediate inclination which appeared with the given content and was later confirmed by the reflective criteria. Are not these criteria, then, really products of the judgment and not the cause of it?

Against the validity of this interpretation we urge the following points:

(1) In the first place, the D judgments constitute but 10 per cent of all the old decisions returned. Even if we add to these the A1 judgments we can only account for about 30 per cent of all the old reactions without taking into consideration the cases where differences in the immediately observable content were undoubtedly present. If it were a matter of probabilities, which is the more likely, that criteria were overlooked in 10 per cent of the cases or that the subject was not influenced by differences in the two situations which occurred in 70 per cent of the judgments?

(2) In the second place, the preponderance of new judgments cannot be due to the reasons alleged. For if they were valid, and if all decisions were the result of an unmediated meaning, of an ultimate consciousness of reference, the preponderance should be noted among all doubtful judgments. We find, however, that 51 per cent of the B_1 and B_2 judgments classed the content as old. Consequently, if all decisions are due to an ultimate consciousness of reference how is the fact that new judgments erroneously predominate only when our so-called positive criteria are lacking, to be explained? And if the positive criteria are admitted to be such, why try to set up an unmediated meaning with the C and D judgments when an equally plausible explanation is at hand that does not involve a completely new point of view.

(3) An ultimate consciousness of reference which is in no way connected with other more reflective criteria, should appear during the first instant of perception. All that subsequent thought on the part of the subject can bring about is the arousal of associated ideas, visual images, etc. If judgments of oldness are not due to the latter, but are based on unanalyzable mental func-

tions, the subject should never utilize the products of the period of manipulation. Under these circumstances the immediate reaction should be final. In fact Katzaroff, who is a strong supporter of an ultimate feeling of familiarity, declares that the latter is the first step in the process. This fact has a number of important implications connected with our problem. In the first place the criteria of the reflective type either confirm the initial inclination or alter it for the better. If they were really superfluous, they should never do the latter. The initial inclination should be the most reliable guide. In the second place it is hard to believe that adult individuals would keep consciously referring (as often occurs, though not always) to factors that are really superfluous. In the last place I was fortunate in having a test which was taken in connection with a later experiment which bears directly on the point at issue. Subject Jo. who served in experimental series II, told me he always gave his initial inclination, (in those cases where there was doubt as well as in those in which the percept itself mediated a certain decision), as his judgment. Here then we have a case where we may see what is the effect of judging on the basis of the initial inclination alone. This series, concerned only with the time, is a much better basis of study than would be the series which are complicated by all the subsequent developments in the course of introspection. Jo. was working only with series in which the order was changed, under which conditions the decisions are generally characterized by a high degree of correctness. There were seventy judgments where the alteration introduced was known, of which 41 or 59 per cent were correct. Of forty-four judgments where the alteration was unknown, 29 per cent were correct. In the known series, there must have been a number of the judgments of the types A_1 and A_2 present. If we take the normal proportion of these calculated on the basis of our eight subjects used in the present experiment, we may say that these represent about 48 per cent of the total number of cases. This would leave thirty-six instances (52 per cent of 70) where there was merely a vague initial inclination, and not the immediate and certain reaction involved with A_1 and A_2 decisions. As

on the average, 83 per cent of the A_1 and A_2 judgments are correct, we can subtract 28 of them from the total number of correct decisions leaving 13 and 6 from the incorrect decisions leaving 23. This means that of the judgments returned on the basis of an initial dubious inclination, but 36 per cent (13/36) are correct. When we compare this percentage of correctness with those found with the A_2 (89 per cent) and B_1 and B_2 (72 per cent) judgments which include classifications of both oldness and newness as do those now under discussion, we can see what a difference there is between relying on reflective criteria and trusting a doubtful initial reaction. We may safely say that the initial inclination is nothing but the reaction which the subject, primed to make a decision in one direction or the other, since this is the "Aufgabe" of the experiment, experiences as soon as the material is presented. The fact that the judgments which are finally returned are generally fairly accurate leads one to believe that the subsequent developments during the process of judging, the use of reflective criteria, are absolutely vital. It is easy to understand the existence of the initial inclination, for the decision is a real process, a gradual development, and when set for such a thing, the subject naturally, even at the beginning, does not approach the problem completely without bias, but always starts with a more or less tentative reaction which is then submitted to constant revision. The difference between the initial inclination reported by Jo. and the negative criteria lies in the fact that the one represents the immediate reaction prior to any period of reflection, while the other consists in the continued absence for a moderate period, at least, of any mediating content, (even though the subject is not reflectively conscious of the significance of this fact).

For these reasons we believe that the twenty-five old judgments which were characterized by doubt unrelieved by the appearance of any reflective criteria are to be accounted partly as being guesses, partly on the supposition that criteria really present were overlooked, and partly, perhaps, by the fact that our concepts were not adequate to grasp certain relatively unusual differences in the content. That the subject should be inclined to

disregard the lack of associates, etc.; *i.e.* that he should refuse to allow content peculiarities to mediate his judgment, is easily understood when we remember that C judgments are very likely to lead to error. The subject must be more or less aware of this in his daily life, and hence we may expect to find him disregarding the warnings given and returning old judgments in place of new. We conclude by calling attention to the fact that it would be a suspicious state of affairs indeed if there were no exceptions to the general principles which we believe that we have established.

These six types of judgment exhaust all cases where decisions were returned. We never attempted to take any account of those cases where the subject was unable to arrive at any conclusion. They do not represent bona fide judgments of either type, and hence cannot be incorporated into our results. The following table gives the distribution of judgments for different subjects.

TABLE XX

Subjects	A^1	A^2	B^1	B^2	C	D
B	29	19	13	14	7	25 (in all)
J	10	7	11	11	16	
F	17	36	15	24	15	
Fe	14	24	3	7	8	
H	13	29	8	8	2	
Fo	12	24	7	20	11	
P	16	15	2	20	21	
W	21	28	8	12	12	
	18%	30%	$\underbrace{}_{30\%}$		15%	7%

We note that the distribution of judgments among the different classes varies with the different individuals, and that no absolute rule can be laid down in this matter.

IV. EXPERIMENTAL SERIES II

This series was concerned with the speed of the judgments. The technique was the same as that used in the previous series except that the interval of an hour was kept constant, and that the only alteration introduced was that of order. Known and unknown series were, however, used. The subject had a stop-watch in his hand. The experimenter gave a warning "now," and then opened the shutter as quickly as possible. The subject started the watch as soon as the percept appeared and stopped it as soon as the decision was reached. The unit of measurement thus obtained was one-tenth of a second.

We divided the judgments into four classes, old sure and old doubtful, and new sure and new doubtful. The decisions of most of the subjects were very unevenly distributed among the four classes, and as a consequence the results given by any individual are only reported in the groups which include a fair proportion of the decisions. In the following tables we compare the results given under the different groups *inter se,* in an effort to see whether there are any significant differences. In the column headed "difference of averages," we indicate by a letter, O or N, etc., whether the old or the new judgments take more time.

TABLE XXI. KNOWN SERIES

Sub	*Number of Jds.*		*Average*		*Diff. of Ave.*	*Prob. Error of D. of Av.*	*Ratio*
			Old sure vs. *Old doubtful*				
	Sure	*Doubt*	*Sure*	*Doubt*			
Kj	16	14	4.84	6	D 1.16	.42	2.7
			Old sure vs. *New sure*				
	Old	*New*	*Old*	*New*			
Jo	29	14	1.96	1.95	O .01	.09	.1
H	7	7	2.2	3.51	N 1.31	.38	3.4

TABLE XXII. UNKNOWN SERIES

			Old sure vs. *Old doubtful*				
	Sure	*Doubt*	*Sure*	*Doubt*			
Kj	8	6	5.45	5.45	000		
			New sure vs. *New doubtful*				
Kj	6	8	6.33	6.88	D .55	.7	.71
			Old sure vs. *New sure*				
	Old	*New*	*Old*	*New*			
Jo	22	17	1.87	2.13	N .26	.145	1.7
Kj	8	6	5.45	6.33	N .88	.645	1.3
			Old doubtful vs. *new doubtful*				
Kj	6	8	5.45	6.88	N 1.43	.74	1.9

TABLE XXIII. KNOWN VS. UNKNOWN SERIES

	Kn.	*Unk.*	*Kn.*	*Unk.*			
		Known old sure vs. *Unknown old sure*					
Jo	29	22	1.96	1.87	Kn .09	.111	.81
Kj	16	8	4.84	5.45	Unk .61	.52	1.1
V	13	12	1.24	1.18	Kn .06	.2	.3
		Old doubtful Known vs. *Old doubtful Unknown*					
Kj	14	6	6	5.45	Kn .55	.57	.9
		Known New Sure vs. *Unknown New Sure*					
Jo	30	17	1.95	2.13	Unk .18	.15	1.2

There are no significant differences, as no difference in the averages exceeds 4.5 times the probable error of the difference of means. On the other hand we note that such differences as exist tend to show that new judgments are slower than old and doubtful judgments slower than sure. It is probable that more significant variations could be found with a more delicate means of timing.

V. EXPERIMENTAL SERIES III "SELECTION METHOD"

(1) Technique

The purpose of this experiment was to see what factors are operative in the selection of an old object from among a number of new ones. When there are a number of possibilities, how do we proceed to pick out the old individual? The technique was the same as that used in series I, except that at the time of the second presentation the first member only of each of the old pairs was exposed. After five seconds the shutter was closed and ten individuals, one of which was the second member of the pair in question, were laid out in front of the subject. The task was to pick out the old individual which the subject knew to be present. Questions were then asked as to what took place during the process of decision.

The subjects used in this experiment were P. and A. (Miss Abbott).

Quantitative Results.—P. selected the correct individual in 23 (77 per cent) cases out of 30, and A. in 11 (64 per cent) out of 17. It is thus obvious that the subjects were generally able to pick out the old individual among the new, although the chances were one in ten.

Method of Work.—Except in five cases with P. and two with A., the problem reduces, so far as the introspecting subject is concerned, to the sensory recognition of one of the ten possibilities. Whatever value the presentation of the initial member of the old pair may have as an aid in picking out the correct individual, this influence is not one that the subject is aware of. Consciously he proceeds as he would if we omitted the first part of the work and laid down ten individuals before him with the instructions that he should indicate which one of them had been seen before. This means that we are here concerned, not with the question as to whether the relationship of the initial indi-

vidual and any specific one of the ten possibilities is old or new, but whether the relations between the elements of the specified stimulus are old or new. Our elements are not the two members of a pair but rather the constituent parts of the individuals presented as possibilities. The question is, did the subject see the letters B-E-M together, etc.? With colors even this relation seems to be lacking and the issue becomes, Was a yellowish green related to past experience? Here the subject-object relation, always implicit, becomes explicit and appears to be the only relation involved.

There were, however, six instances in which the idea of the second member of the pair was recalled when the initial individual was re-presented. When the ten alternatives were laid down, this one was then picked out. All of these judgments were correct. It might be asked what reason the subject had for accepting the suggested idea. The answer seems to be that the mere fact that it was called to mind by the presented stimulus guaranteed that its percept had in the past accompanied the former. We have previously had occasion to refer to the fact that the arousing of an associate will, with many subjects, bring about its acceptance. The position is here substantiated by the fact that there were no cases in which a single possibility was suggested and subsequently rejected. This matter was specifically brought out in the reports. Once also P. said that he associated the initial member of the pair with a syllable possessing a certain type of auditory quality. When the ten alternatives were subsequently presented, he worked over them all until he found the one which came the nearest to possessing the auditory quality anticipated, and then accepted it. The decision was correct. In conclusion we may lay down the following rule. The presented stimulus (the first member of the pair) either arouses no idea of what accompanied it in the past, or that which is suggested is considered a valid product of memory. In the former case the problem, so far as the subject's conscious procedure is concerned, becomes that of recognizing one of the ten possibilities.

(2) Cases where there was Conflict

We include under this head the cases where a real question arose as to which of two or more of the presented alternatives was the old stimulus. These were, of course, the instances in which we were particularly interested in this experimental series. It gives us a chance to observe the basis for judgment when doubt is present. There were five such judgments with A. and eleven with P.

Action of the Attention.—The general rule seems to be that the attention slides over the rejected individuals, giving no heed to them, but is attracted to or "snagged on," if we may use the term, the content which presents itself as a possibility. There are two possible interpretations of this phenomenon. On the one hand, the action of the attention may be regarded as being a result of the instructions and of the fact that the possible old character of the selected individual is distinctly felt. The attention is held because the content may be old and the old individual is the center of interest in virtue of the "Aufgabe." If this explanation is correct the attention should be attracted to the content only when the latter has presented itself as a possibility. Previous to its isolation on this ground, the attention should go from one individual to another, judging it old or new as the case may be. We should have each individual taken up in order, and then the possibilities should hold the interest for a relatively long time. This statement may seem to overlook the fact that the subject may immediately pick out the individuals which may be old, ignoring the rest. It is conceivable that the former stands out of the lot to meet him, so to speak. Many of the recognitions (or possibilities of recognition) are, however, due to associations and visual images. It is difficult to understand how these could put in an appearance during the first cursory sweep of the eyes over the alternatives presented, and hence attract the attention to the content with which they are concerned. It would appear rather that they should come in when the attention is specifically held on the content in question. The felt possibility of recognition should arise under these circumstances

only after the individual has become the center of interest. Now the fact is that the rejected individuals are never attended to at all. They are for all practical purposes non-existent. Does this not seem to indicate that the attention is attracted to the possible individuals immediately on presentation and that this very prominence in the focus makes the subject consider it possible that the objects are old and familiar? Bourdon has mentioned that content which is interesting and attracts the attention tends to be recognized. We believe that he is right and that the ability to attract the attention is the first step in the recognitive process. What can assert itself in the focus is considered as very likely to be old.

Associations.—A. reported one instance in which one of the two possibilities aroused an associate and was accepted. Twice besides associates appeared, but they were so general that they applied to both alternatives equally well, and hence had no influence on the final choice. P. accepted five individuals which aroused associates more immediately and spontaneously than did those which were rejected. Four of the judgments were correct. Once the stimulus fitted in better with certain anticipatory qualifications. This has already been referred to (method of work). In another case, the individual chosen fitted the verbal description incorporated into the association better than did the rejected content. Finally, in one instance, there was no difference in the immediacy of appearance of associates mentioned, but the name which was the first associate aroused by the accepted stimulus was followed by a train of ideas, while naming was the sum total of the process accompanying the other individual. The decision was correct.

Visual Images.—A. and P. both employed visual images as criteria. The former classed two visual images of themselves aroused by alternatives as artifacts, leading to the acceptance of the other possibility. One of the decisions was correct. The following are the peculiarities which A. reported as differentiating an artifact from an image considered to represent the past.

(1) Artifacts are always imaged on a background which has sharp outlines separating it from the surrounding space. Ac-

cepted images, on the other hand, appear with backgrounds which fade off into the rest of space. (2) Accepted images are good and gray (the only images obtained were of letters, geometric forms and syllables, never colors),—while the artifacts were characterized by being washed out, or as A. put it, by the presence of non-colored letters. (3) Artifacts are located nearer in space than are the accepted images. Altogether, as A. put it, it is much the difference between a sign-board and a normal percept. In a third case, there seems to have been no difference between the images of the different alternatives. The decision was very doubtful. We shall, in the remainder of the work, classify such judgments characterized by doubt and the absence of any observable introspective criteria, under the heading E.

We found four instances with P. where the accepted alternative called forth a visual image of itself and the rejected one did not. All the decisions were correct. Once the image of a gray was not specific enough to mediate a decision between two shades, verbal description being the deciding factor. In two cases there were images of both alternatives and no difference could be discovered between them. One of the decisions was the result of the immediacy of an association; the other was of the type E, and was incorrect. We may then say that whenever there is a conflict and one of the alternatives arouses a visual image while the other does not, P. accepts the former. Where there is an image with each of the alternatives, and no difference of any type is detected, the decision is either rendered on other grounds, or, these failing, is doubtful and probably erroneous.

Motor Phenomena.—A. mentioned a case where a number of alternatives aroused an impulse to reach out and pick them up. She accepted the one with which the strongest motor reaction was correlated, which resulted in an error. This is a type of criterion we have never met before. It will receive more notice later.

There remain three judgments returned by P. all of which belong to the type E.

Other factors.—We were unable to find any other differences in the content accompanying the accepted and rejected alternatives. Of especial interest there are the reports of subject P., who

reiterated over and again that his recognition consisted consciousness that he had experienced the content before, a nothing whatsoever to do with a feeling of familiarity results in this series confirm those gained earlier in regard irrelevance of organic sensations, affective processes, etc., as the phenomenon of recognition is concerned.

(3) Cases where there was no Conflict

There were, in addition to the judgments where the was doubtful as to which of two or more of the alternati really the old individual, a large number of cases where t ject never considered more than one individual as a pos It might be that he was far from sure that this choice w rect, but the doubt never led him to work with any other stimulus. P. reported 19 (63 per cent of all) such jud and A. 12 (70 per cent). These decisions add but little t we have already observed and we will give them but short

Associations.—The general rule is that associates appe with accepted individuals. This happened in five instanc subject A. All the judgments were correct. P. reporte with one exception, every accepted individual aroused ass and that one rejected stimulus did the same. In contras procedure in Experimental Series I, P. never named any or geometric forms except those which he judged to be old difference in the two results is easily understood, howeve we consider the difference in the conditions of work. In ment I, each pair is the subject of an overt judgment. This that the attention is voluntarily focused on each group. T ural result is to increase the chances that any more or less h reactions, like the naming of colors and forms, will be The latter were therefore regarded with suspicion, a hig flective way of stating the matter, as being possible prod the existing situation. Under the present conditions, the m entirely different. The instructions themselves do not b about that each individual is a point on which the attentio quired to dwell in an explicit manner. Consequently wh attention is held up by the fact that a certain stimulus h

named, the subject will have more reason to believe that this latter is due to a tendency established at an earlier period and will accept the implication. That there is still, however, a certain amount of wariness in the matter is indicated by the fact that P. never considered a circle, which he had named, as likely to be the old individual. The thing is too absolutely habitual to gain any credence.

Visual Images.—Accepted individuals were the only ones which were accompanied by visual images of themselves. P. reported four cases and A. six where the latter were present. A. judged old four individuals on this basis alone, while with P. there were always associations present in addition.

Motor Phenomena.—A. said that two recognitions were due to an immediate impulse to reach out and pick up the accepted individual. One decision was correct. We have already mentioned the fact that this is a novel criterion which we have not encountered in our previous work.

Other Factors.—No other factors were isolated as of any importance. We could at no time isolate a feeling of familiarity.

Classes of Judgments.

Cases with conflicts						*Cases without conflicts*					
Subject	A^1	A^2	B^1	B^2	*E*	*Subject*	A_1	A_2	B_1	B_2	*E*
P			2	6	3	P		10	1	6	1
A			1	3	1	A	1	8		2	1

(4) Conclusions

As a result of experimental series III we reach the following conclusions:

1) Where the conditions are not such as to bring about the voluntary concentration of attention on every individual object, the only items attended to are those which are accepted or those which are considered as candidates for acceptance. This is not due merely to the fact that the "Aufgabe" is to pick out the old unit, as that would only account for the prolongation of the attention on an individual after it has once come to be considered as possibly old. It would not explain why *all* the different individuals themselves are not centers of interest requiring each a judgment of novelty or oldness. It does not explain the sweep-

ing of the attention over them without taking any note whatsoever of their status. We believe hence that whatever attracts the attention tends to be recognized, and that this ability to assert itself in the focus is the first step in the recognition of any object.

2) In cases where there is no conflict we find that the only content arousing either associates or visual images or motor reactions is that judged old. The other content has no such effect. Where conflicts occur we find that the alternatives which are considered as possible may arouse associates, visual images or motor reactions. The basis for decision in the case of conflict may be 1) the presence in the one case of an associate while in the other it is lacking, 2) the same for visual images, 3) the immediacy vs. delay of associates, 4) the arousing of a train of subsequent associations by the initial idea as vs. the failure to do so, 5) the peculiar character of the visual image aroused (artifact), and 6) the relative strength of the motor reaction set off. It is obvious without detailed statement that these are all capable of being brought into relationship with one another by being classified as manifestations of the working of the principle of habit.

VI. EXPERIMENTAL SERIES IV VOLUNTARY RECALL AND PROMPTING METHOD

(1) Technique

In the previous series we presented a number of alternatives to the subject and asked him to pick out the old individual. In the present work we were interested in seeing what were the factors involved in recognizing content which the subject has himself voluntarily recalled without assistance. The problem may be well illustrated by the question, "When I try to remember a man's name what guarantee do I require of any possibility that presents itself before I accept it as the content desired?"

We also wanted to see what effect would be produced by increasing the articulatory processes if possible. Heretofore the stimulus had always been given visually and the subject used whatever imagery he desired in apperceiving the content. Though we have noted the presence of articulatory imagery in a large number of cases, it has been of value on its own account only with H(rhythm), and then only in isolated instances. Otherwise it has merely served as the carrier of meaning with the associates. It now becomes a question whether there are any peculiarities of the process itself which can serve as a basis for differentiation in a manner analogous to the stability of visual images.

In order to test these points we employed the following technique. A series of names of battles or treaties chosen with a view to their obscure and unusual character were read aloud to the subject together with the corresponding dates. Each series consisted of six such units. The names were read one at a time with the appropriate date in the tempo of about four seconds for each. After each pair the subject repeated aloud the name and date. Following the lapse of about two minutes after the completion of the series the experimenter picked out one of the names from the list, being careful to vary the position of the one

chosen in the different series, articulated it aloud, and asked the subject to give the corresponding date. If the subject found a date that he would accept, he reported it and careful introspections were taken. If the subject could find no date which he would accept, he reported this fact to the experimenter and the latter then suggested two possibilities, one of which was correct. These also were given auditorily. The subject knew that one of the alternatives was what he was looking for and made a choice between them. Careful introspection were then taken concerning the mental processes involved in the decisions. Two dates from any one list were the maximum used in a test.

There is one point that should be noted here. Inasmuch as the interval between the initial series and the test was short (it had to be as the problem was difficult) we might expect to find what we called the carrying over of the past by the percept itself oftener in this experiment than in the first one. The result of this may not be a judgment of the A1 type, where the accepted content is perceived immediately and surely as something that has been experienced before, the sensory material itself arousing the meaning without the intervention of any ideational criteria. Rather we might anticipate that there would be an initial bias, an initial inclination in one direction or the other which necessitates further testing before the judgment is finally decided upon. This inclination would differ from that reported in series I in the greater degree of subjective surety accompanying it and in the fact that it normally influences the subject to the correct decision. We found that our anticipations were correct.

The questions asked the subject during the course of the introspection were as follows: (In case the subject was able to find a satisfactory answer without having the alternatives presented by the experimenter.)

Is this the only possibility that presents itself, or do you select this from among two or more alternatives? In what imagery terms does the date appear?

(In case there was only one possibility.)

Were there any associates aroused by the name of the battle which were instrumental in determining the date? Or was the

date when it suggested itself accompanied by associates, or followed by them?

Did you get a visual image of the date? If so, was it clear and distinct (outline or Schärfe), stable (in space), permanent (as opposed to fleeting), detailed? Were there any other factors of note here?

Did you articulate the date? Was there anything notable about the articulatory process? Did the attention once focused on the process run over the whole series of digits at one swoop without any interruption or was it held upon or attracted to any specific digit as you articulated it? After the articulation was once started (which of course involves a certain amount of initial voluntary control), did the series of digits run off more or less automatically one unit following the other without any hesitation, or is there need of more or less voluntary guiding during the whole articulatory process? Are there digits the saying of which interrupts the spontaneous flow of the articulation, involving a certain amount of readjustment before you continue?

(The latter was illustrated by the example of reading Greek words.)

Are there any motor phenomena which appear when the date comes to mind, a motor clinch, etc.?

Is there any mood or affective tone present, or are there any organic sensations to be noted?

(In the cases where there were alternatives.)

Are you sure of your choice? Which alternative came first? Which was more spontaneous (involved less voluntary search and manipulation)? In case there was a visual image, was there any difference in the assertiveness of the images? Did one keep tending to force its way into the focus of attention? Was there any difference in the assertiveness of the ideas themselves? Did one tend to keep recurring to you even when you were not looking for it, or even when you were interested in another possibility? The other questions given above were also included in this introspection.

The subjects used in this experiment were Bi. (Mr. Bickle), and Wy. (Mr. Wylie).

(2) CASES WITHOUT PROMPTING

Bi. returned fifteen judgments (36 per cent of all) prompting. Of these, 53 per cent were correct. Wy. same in 20 cases (71 per cent of all). Of these, only cent were correct. There is thus no rule that can be laid The necessity for external aid seems to vary from indivi individual.

Bi. reported that only one possibility occurred to him instances where he recalled the date in question without the same thing was noted by Wy. eleven times. Unde conditions we say that there was no conflict.

Cases with No Conflict.—We find the following are th in which dates appeared:

1) *Visual Images.*—With Bi. the name of the battle a visual image of the date. These images might be vag fleeting, but provided there was no alternative, they w cepted as valid. There were seven such images arous four cases they appeared in a definite place in a visual representing the series of six dates and battles. Twic attended the judgment. We are here able to point out the for this, as in both instances the image was delayed. Tl was the trouble was shown by the fact that with one da of the four digits came immediately and were accepted hesitation, while the two delayed digits were question addition, it should be noted that these are the only in judgments. The remaining images came immediately o tically so (one case).

2. *Auditory-Articulatory Imagery.*—Bi. often heard th pronounced and in addition words indicating the locus particular item in question in the initial series were h three instances. Two of these decisions were those r when no visual image was present. Articulatory imag companied the auditory on occasion. Once only, howev the articulation characterized by any notable property. T curred with a doubtful judgment in describing which I that the last two digits did not run off automatically, b

hesitation was noticeable at this point, which called for a volitional thrust to bring the process to a close.

With Wy. the date appeared immediately in auditory-articulatory imagery. In one instance, owing to great delay in its appearance, a date was rejected. Once Bi. also rejected the only alternative that offered itself. The date that put in an appearance was recognized to be one that had been concerned with the pair just preceding. We may say then, in conclusion, that provided no alternative is present, whatever suggests itself as a solution of a specific problem of memory is accepted by these two subjects, unless (1) it is too delayed in its appearance, or (2) it brings with it a definite reference to a different series. These latter conditions vary for the different subjects.

Cases where there was conflict.—There were six such judgments with subject Bi., and nine with Wy. The following are the factors that stand out as differentiating the accepted from the rejected content.

1. *Primacy in Time.*—This was used by subject Wy. In six cases, the first suggestion was accepted. There were in addition to the nine cases mentioned above, two where no decision was arrived at in regard to the alternative. In both of these, then, primacy in time is not sufficient to bring about the acceptance of one of the alternatives. Still, in 75 per cent of all the instances reported, the first suggestion is accepted, other things being equal.

2. *Associates.*—Twice the first suggestion was not accepted owing to the fact that the later date brought with it a train of associated ideas, which the former lacked. Both of these decisions were reported by Wy.

3. *Persistence.*—On one occasion Wy. accepted the date which kept forcing itself into the focus of attention in lieu of the initial possibility.

4. *Characteristics of the Visual Image.*—With Bi., three visual images of the accepted date came placed in the schema of the whole series while those of two of the rejected alternatives did not. In two of these cases, the accepted image was clearer (better outline, less vague), more permanent (not so fleeting), and

in one of them the figure appeared in more bold faced ty
visual image of the third rejected individual came at all.
last named peculiarities seem to have been of value, but t
point appears to have been the presence or absence of t
ciated image, the schema. Both of the alternatives wer
rect in two of these instances; in the third the right d
erroneously rejected. On one occasion, both the alte
placed themselves in the visual schema of the old serie
more assertive individual was selected. It was the one
as Bi. said, kept "recurring." The other image did not
this property to such a marked degree.

5. *Ease of articulation.*—Twice Wy. accepted the date
ticulation of which was the more automatic.

We note in addition that Wy's reports indicate the
ing differences between doubtful and sure judgments
Whatever content presents itself immediately and withou
is, other things being equal, accepted without hesitation
when delay and a period of voluntary effort is involved i
ing dates, the later are regarded with doubt, even if accep
had to choose between two alternatives on two other oc
Once the first possibility that appeared brought with it
ciation with a different battle, and hence was judged wr
second date being accepted. In the second case, Bi. said
had been thinking of the date in question before it wa
for, and hence the alternatives were of no use. These are
speaking not conflicts. The matter never comes to a re
There were only two correct judgments with each subjec
was due to the fact that both alternatives were often inc

(3) Cases With Prompting

Often the subjects could not come to any conclusion
matter of the date required without being prompted. So
this was due to the fact that no dates at all appeared, e
maybe isolated digits, such as the century in question, but
exact year. At other times the subject was unable to f
grounds for deciding between two possible alternatives t
sented themselves. Under these conditions the experime

fered two possibilities in the manner indicated above. Bi. received assistance in this way twenty-seven times making twenty-five correct decisions. Eight of Wy's judgments were of this type, seven of them being correct.

Initial Inclination.—Owing to the short interval between stimulus and test, there was a tendency for Bi. to conceive a preference for one of the alternatives immediately when the experimenter articulated it. This occurred in nineteen of the twenty-seven instances. Only four of these judgments, though, were of the type A1, *i.e.,* so certain that no appeal to reflective criteria was necessary. This is extremely interesting, as we seem to have here transition cases. The past is not so completely incorporated, so to speak, into the present that the meaning—the reference—is called out in an ultimate manner by the static and unyielding sensational content itself, nor is it so completely obliterated that the subject is forced to rely entirely on the imaginal and reflective criteria. There is rather a tendency to perceive the content as old immediately, but it is not strong enough so that Bi. foregoes the appeal to further evidence. It is furthermore to be noted that the reflective stage of the decision never changed the decision for the worse. Once it even forced the acceptance of the date which was initially the more unfamiliar. The decision was correct.

The following criteria were appealed to:

Anticipatory Images.—In three cases, Bi. had been working with material before the alternatives were suggested. When the latter occurred, he found that one of the two offered corresponded in part with some of the details (the century) that he had already worked out, and in consequence accepted it. Wy. reported the same phenomena once. Three of these four judgments were correct.

Difference in the Articulatory Processes.—Eight of Bi.'s decisions resulted from the fact that the articulation of the accepted alternative was the more automatic, no hesitancy being noticed in the saying of any of the digits. Bi. used such terms as: "It runs more glibly." "There is no hitch before the last digit." "The attention does not guide the process continuously, there

is no voluntary push in order to complete the number." It is obvious, of course, that the repetition of the two alternatives, one after the other, is a highly reflective process and hence the appeal to this mode of decision always involves volitional factors. The difference seems to be that in the one case the articulation runs off in an automatic and easy way, the sequence of laryngeal movements being unguided, while in the other, the volitional factor persists throughout the whole process, each successive digit being felt as a distinctive individual, not as a mere continuation of a process already under way. Wy. appealed to this same criterion four times. In addition to the description given by Bi., the former said that it was less of a volitional matter to start the flow of auditory imagery of the date with the accepted content and that it was easier to turn from the image of the new to the old than vice versa, *i.e.,* the mental inertia to be overcome was greater in one case than in the other. All of the judgments returned by Bi. and three of those with Wy. were correct.

Visual Images.—These were employed by Bi., never by Wy. The following characteristics of the images were used as a means of differentiating the old and the new.

1. Greater Permanence. By this we understood the tendency of an image to maintain itself for a relatively long period of time, as opposed to a fleeting character or a tendency to fade out and disappear quickly. Four decisions were due to the selecting of the date arousing a more permanent image of itself; they were all correct.

2. Completeness. By this, we understood the character of an image as detailed and filled out in respect to the different items that one would expect to find in the percept of figures, as opposed to a scrappy, incomplete content. There were four cases where the accepted image was more complete.

3. Place in the Schema. On four occasions the image of the accepted date appeared placed in a schematic representation of the series or column of names and figures which Bi. built up at the time when the stimulus was given the first time. The rejected images were not so placed. The judgments were correct.

4. Persistency. By this we mean the greater tendency for one image to usurp the focus of attention. It will return persistently, without being sought, while the other image will not. This was used as a criterion twice. One judgment was correct. As Bi. put it, "the one returns on its own account, the other only when I go after it."

5. Associations. An association mediated one decision returned by Wy. Once Bi. rejected an alternative because he said that as it represented a number possessed of peculiar mathematical properties, he would have recalled it himself if it had been a member of the initial series.

6. *Auditory Quality.* In one case Bi. tried to hear the two dates articulated in the voice of the experimenter. He accepted the one with which he succeeded, which was correct.

We can thus account for all but five of Bi's judgments and for all but two of these returned by Wy. Of the former, four were decisions of the class A1 and one of the class E. Both of the Wy.'s reports were of the class A1.

(4) Conclusion

We find that: 1. In a good proportion of the tests both subjects recall the dates themselves. With one exception where a long interval intervened before anything suggested itself, a date is accepted provided there is no conflict. The mere ability to arouse a definite idea in the case of a problem where we are trying to recall terms, will be the basis for regarding it as correct. If alternatives are called up, we find that the subjects employ different criteria. With Bi., the decision is based on (1) the relative assertiveness of the visual images; (2) the ability to arouse associated images representing the original situation, *viz.*, the schematism. Wy. selects the first, the more persistent, and that which arouses associates. Ease of articulation also plays a part with both. These peculiarities are, of course, easily subsumed under the concept of habit. The first thing that we think of is usually the most habitual. The habitual reaction tends to assert itself, and the arousal of associates, or of a visual setting, is the result of overflow into preformed pathways.

2. If no possibility suggests itself or if there are no differences on the basis of which the subject can decide, he must look for outside help. Different subjects then appeal to different criteria in deciding between suggestions offered. Some criteria are common, however, to both Bi. and Wy. Of this type are ease of articulatory sequence, anticipatory images and the relations of associates. Bi. employed in addition the relative completeness, permanency, and persistency of the visual images, their ability to bring associates (schema), and also the ability to reinstate a highly familiar auditory quality with one of the alternatives. It is of course perfectly obvious that these also can be subsumed under the principle of habit.

3. We have also noted that by shortening the interval we are enabled to find transition cases between the judgments mediated by the percept, of the type A1, and those where whatever inclination is present at first is no better than a mere guess (Jo. in series I). We have, of course, already admitted that our concepts may not have been adequate to isolate criteria (other than the percept) which were actually operative in determining the A1 judgments. On the other hand, we have given certain reasons for believing that we have under these conditions decisions which are due to perceptual criteria. The intermediate cases noted in the present experiment when the interval is relatively short indicate that there is a gradation in the strength with which the past can assert itself through the stimulus alone. Starting from judgments of the type A1 which are perceptually mediated, certain, and reliable, we descent through the judgments where the initial inclination is usually correct but is not accepted as final, to those where the initial inclination is a mere guess (see Jo. series I). These latter always necessitate a reflective testing. We have already pointed out that the intervals employed by many previous experimenters have been exceedingly short. It appears to us that in the light of our conclusions they were by this very fact prohibited from seeing the whole range of the recognitive reaction, and as has been said before, from taking note of the criteria appealed to in case of doubt. They were really dealing with A1 decisions a good part of the time.

VII. EXPERIMENTAL SERIES V. OPPORTUNITY FOR INTELLECTUAL ANALYSIS LIMITED. EFFECT OF CONGRUITY WITH CONTENT

(1) Technique

The object of this experiment was to determine two points: 1) When no opportunity to work over the material in a highly reflective manner is afforded, what criteria are present, at the time of the report, with the content which the subject believes that he perceived. In other words, what characterizes the conscious processes involved when the subject recalls such material immediately following its presentation?

2) What influence, if any, does the presence of congruity with a larger context have in determining what will be accepted?

Method. We used an ordinary fall tachistoscope, employing as stimuli cards on which were groups of typewritten words. The number of words varied from three to five on the different cards. Sometimes the former were arranged so as to make sentences, while at other times there was a number of unconnected words. The cards of both types were mixed in the order of their presentation, so that the subjects had no knowledge of what to expect. The subject sat in front of the tachistoscope and fixated a point over the place where the middle of the group of words would appear. The experimenter gave a warning, counted three aloud, and released the shutter. (The time of exposure was about 1/10 sec., being the normal exposure used in tachistoscopic work.) The subject then reported what he had seen, and introspections were taken. The questions were practically the same as those employed in Series IV, except that the matter of articulation received less attention unless the subject indicated that it was of importance.

In this way we were able to achieve the conditions that we were interested in. The subject had no time while the shutter was going down to indulge in intellectual analysis and the two

kinds of material gave us light on the influence of context. On the other hand it is worthy of note that under these conditions we are not, strictly speaking, dealing with the phenomenon of recall or memory. For if we accept James' doctrine that memory always implies a period intervening between perception and recall, during which the stimulus is not an object of thought, the present series returns no instance of memory. The subject is constantly concerned with what he saw from the moment the shutter falls to the moment when he makes his report. Inasmuch, though, as this report is made after the stimulus has been removed, and hence refers to a past content of consciousness it must throw light on the processes involved in deciding what has been experienced at an earlier time under conditions which preclude a period of mental manipulation. In this sense, then we shall speak of the process here investigated as recall. In ordinary life we find the counterpart of this situation whenever owing to any cause whatsoever we are called upon to decide what we perceived in the course of a brief and hasty survey. Finally, we see no reason to believe that whatever influence of context is demonstrated may not be considered to hold good even where we have genuine recall. There would be no difference in the conditions that should alter our general results. Our interest in this part of the investigation was entirely different from that actuating the work that has been done so thoroughly at different times with the same technique. The interest generally lies in the question of what influence context has on the scope of attention, on the number of items correctly or incorrectly perceived. We are not here concerned with the quantitative side but rather with the question as to what influence context exerts in leading to the acceptance of ideas which memory throws up as being representations of the past.

The following report refers to all the content reported as perceived, both that which at the time of the fall of the slide stood out clearly in the focus of attention and that which was but vaguely cognized as lying in the fringe. Both types of material are at the time of the report referred to the past. For any one interested in differentiating between the two, we call attention

to the fact that all cases of rejection, conflict, and a highly doubtful character are to be grouped with the content but vaguely perceived.

(2) Non-Consecutive Material

The subjects used in this experiment were A. and S. (Dr. Sutherland). In thirty-seven cases the material did not form sentences with A. and in thirty-six with S. It is impossible to give anything like a fair quantitative report of the number of correct and incorrect items returned, as in many cases only individual letters were mentioned, in others complete words and in still others a number of letters of a word, some of which were correct and some incorrect. We shall then, in these reports, deal almost exclusively with the introspective data, and where we speak in quantitative terms at all the unit will be the card.

Cases with No Conflicts.—In twenty-four instances, A. reported that she accepted whatever suggested itself without questioning. The same thing was true of thirty of the judgments given by S.

1. Mode of Appearance. A reported that the letters and words returned were all articulated immediately and spontaneously as the shutter fell or just after it. Once when this did not take place, there was a tendency to articulation reported, and on two other occasions grave doubts were expressed as to the validity of the replies, as even this immediate tendency was lacking. The delay in articulation will, then, lead to doubt as to the value of the judgment. A visual image was present in all but six cases. In four of these the articulation came immediately, while in the other two it did not. We see that while the failure to articulate immediately leads the subject to doubt the validity of his reply, the absence of a visual image has no such effect. On the other hand, certain properties of the visual images distinguish the doubtful from the sure reports. Where the background on which the letters appeared was a good white one, and the letters themselves were a clear gray and sharply outlined, not tending to fade into the background, A. felt pretty

sure that the content in question had been on the card. Where, on the other hand, the background was gray and the letters less sharply outlined and clean cut, there was more or less doubt. This seems to have been a basis for distinguishing the two classes of judgments, the doubtful and the sure, but it was never a basis for the rejection of any possibilities that offered themselves.

With S. the procedure was entirely different. Often the word suggested was present as a good clear visual image as soon as the shutter had fallen. These images were, as S. put it, continuous with the percept. As soon as the stimulus was removed by the shutter, the image was just there with clear outlines and complete details. Under these conditions, S. was sure that he had made no error. (These were the words clearly perceived as the shutter went down.) On the other hand, it often happened that S. had merely a blur for a visual image. Sometimes there were isolated letters which could be made out in this blur while at other times even these were lacking. Later the blur would "clear up into" a word. These words were reported but were regarded as being more open to doubt than the others. Especially if the clearing up process was delayed, was S. inclined to look at the result askance. Another source of doubt was the lack of a clear outline of the letters in an image.

Cases Where the Only Suggestion was Rejected.—On occasion, A. and S. both rejected as invalid the only suggestion that appeared. This was noted six times with A. and twice with S. (These are all words which were not distinctly perceived at the time of exposure.) The following were the peculiarities of content found to accompany these judgments:

Construct Character of the Visual Image. We have already mentioned the fact in connection with Series III, that A. regarded certain visual images characterized by definite peculiarities as being products of the present moment and not re-presentations of the past percept. We shall not go into the matter any further at this point (see Series III). Twice the only possibility that appeared was refused credence on this basis.

Length of the Visual Image. A. and S. each rejected an individual owing to the fact that it was too short for the image

of a very blurred character which was carried over from the percept.

Delay in Articulation. With A. on three occasions, no word or letter was articulated promptly and spontaneously as the shutter went down or just following it. We have found that this occurred twice before and both times we noted a strong element of doubt. We may then say that if no possibility suggests itself in articulatory terms, if the subject does not immediately read, so to speak, something to herself, the content that comes up later is very likely to be rejected and at least will be looked at askance. These judgments were all correct.

Fleeting character of the Visual Image. S. rejected an individual the visual image of which faded out immediately, an unusual occurrence.

Cases of Conflict.—A reported seven cases of conflict, in five of which a decision was possible. S. reported four such instances and reached a decision three times. The following were the criteria appealed to: 1. Completeness of the visual image. A said that once a complete visual image of one of the alternatives appeared, while the other image showed only a number of letters. The former was correctly accepted. 2. Lack of Background. A. rejected a word that had no background, while the accepted individual was on a good white one of the type already mentioned. A difference also in the assertiveness of the images was reported, the accepted one tending to recur of its own accord. We have already mentioned the use of this mode of distinguishing between the old content and the new. The decision was wrong, leading to the rejection of the correct alternative. 3. Context. A. and S. each gave the preference to an alternative which fitted in better with the meanings of the other words than did the second suggestion. 4. Relative Assertiveness of Visual Image. Twice S. accepted the more assertive image. 5. Length of Visual Blur. An alternative which was of approximately the same length as the blur which came up in the visual image was judged old by A. 6. Clearness of Visual Image. In one case the image of the accepted individual was clearer than was the other image. (This is not the so-called attributive clearness to

which the structuralists would reduce attention, but is ra matter of the clearness of the outlines and details involv opposed to a blurred character and obliteration of detail.) decision was correct.

We conclude then as follows: In agreement with the obtained in Series IV, we find that all possibilities that s themselves are accepted, provided they come promptly and out effort, and provided they do not conflict with certain p characteristics of the visual image, and provided no alter appear. Where the latter occurs, different criteria are ap to by the two subjects, although some overlap. It will b however, without a detailed statement that these criteria a as may easily be subsumed under the principle of habit conclude, then, that the same rules hold for material wh subject has no opportunity to work over in a reflective r as for that which he has manipulated. This will, it app me, invalidate many conclusions drawn on the basis of ments utilizing distractions.

(3) Consecutive Material

A. reported thirty-eight such judgments and S. thirty-s

Cases with No Conflicts.—In thirty-two cases, A a whatever suggested itself without questioning. This te is thus stronger where we are dealing with material that f meaningful whole, where, *i.e.*, each unit is related to every one by means of threads of meaning, than where we series of individuals which are unrelated. (86 per cent per cent.) The content may come in the shape of a visual or of immediate and spontaneous articulation of the w question. There seems, however, to be no basis for differ ing acceptable material from that which is not considere rect on this basis. Content was rejected only once and instance A. said that it might have been there. The seems to have been that this sentence was rather long a was sure that she had not seen it all clearly. Moreover, t rejected did not appear in a visual image. This, while not hinder content from being accepted, will nevertheless

it to be regarded with questioning. Certain factors led the subject to regard suggestions with a certain amount of questioning even if they did not lead to rejection. Among them we note (1) lack of visual image of the content concerned; (2) a gray background (as before); (3) lack of a clean-cut outline of the letters in the visual image; (4) scrappy character of the visual image; (5) delay in the articulation, (which really means in the appearance, the coming to mind of the content); (6) tendency to fade out quickly on the part of the image.

In contrast to subject A.'s reports, we find with S. that the proportion of instances in which the content is accepted and no conflicts appear is smaller when the stimuli form sentences than when they do not. This then appears to be a matter that varies with the individual, but while this effect of context is not noticeable here, another difference obtains which will be mentioned later. S. accepted the only content which presented itself in twenty-six instances. Sources of doubt were, (1) delay in the appearance of the visual image; (2) vagueness of the image; (3) the tendency of parts of the image to come and go instead of persisting steadily. All the visual images which came late and were accepted were clear. No individual was regarded as valid the image of which was both delayed and vague (blurred, outlines not sharply cut and details well marked).

Cases with No Conflicts Where the Suggestion was Rejected. S. rejected five individuals even though there was no alternative on hand. This occurred but once in A.'s reports (see above). The bases for the decisions returned by S. were: 1. Vagueness of the image *plus* delay (1 case). 2. Fleeting character of the image (2 cases); 3. Violated sense of the rest of the sentence (1 case). 4. Image too long for the initial blur (1 case). All the judgments were correct.

Cases with Conflicts.—A reported only five conflicts, as opposed to the seven with cards not giving a consecutive sentence. This then is the second point to note with her. A definite context not only tends to increase the inclination to accept whatever suggests itself but it also diminishes the likelihood of conflicting alternatives. Three choices were possible. S. reported six con-

flicts, in five of which a choice was possible. The crite
ployed were: (1) Presence of a visual image of one alte
and lack of it for the other. (A) 2. Presence in the visua
of certain letters which would fit in with one alternative.
image was incomplete). (A.) 3. The length of the visu
that was aroused when the shutter went down and whi
sisted over was more compatible with one alternative th
the other. (A.). Two of these judgments were correct.
ter sense with the rest of the context. (S. 3 cases.) 5. M
sertive character of the visual image (S. 2 cases). In t
these instances both alternatives were wrong, once the co
dividual was accepted and once it was rejected. Twice
both of the alternatives made a meaningful sentence, while
occasion the accepted one did. In the judgments recorde
(5), no difference in the meaningful character appear
thus find that in all there were three cases with A. and fo
S. where a direct preference for words that fitted in w
general context in meaning was evinced while we never
choice in favor of an alternative that violated meaning.

(4) Conclusions

We may then summarize the results of these experime
say that context tends to dictate what will be received a
recall either by: (1) Lessening the dissatisfaction with w
pears so that fewer suggestions are rejected (when o
alternative is present) and that fewer cases of conflic
than in the series where no meaningful whole exists,
Furnishing a criterion which leads to the rejection of a
vidual where a meaningful alternative is present. Also
find again that mere appearance is likely to lead to the
ance of a possibility unless there is some criterion of no
connection with it. These criteria are all explicable as
the law of habit. This is so obvious after what has been
former experiments as hardly to need expansion. Even
dency to accept what fits into the context is due to habi
in our normal experience there is some kind of orderlines
kind of a synthesis in meaning terms. Hence where this
ing we conclude that the experience has not yet been s

to the synthetizing processes of the mind, has not been brought into relation with the other factors of the situation. In case of conflict, also, the criteria are of the same general type.

2. In general the same kinds of criteria are used with content which has not been subjected to reflective attention as with that which has been the object of more or less careful observation and thought. It would be well for all those who attempt to prove the absence of reflective criteria as a result of experiments involving distractions, etc., to note this fact.

VIII. EXPERIMENTAL SERIES VI. FURTHER WORK ON THE INFLUENCE OF CONTENT

(1) Technique

In order to test the influence of context more fully we used the following technique. Instead of writing the words one after the other and having them separated by equal spaces, as was done in the previous series, we prepared cards on which were sentences of from three to five words. The last word, however, did not make sense with the rest of the group and it was placed about half an inch to the right of the others (the unit used in measuring was a typewriter space), so that there was three times as much room between it and the preceding word as there was between any other two units. The subject did not know of the arrangement. He was told to fixate a spot over the place where the body of the content would appear. In this manner the outlying word was removed from the region of distinct perception. Still (in many trials) the presence of something at this point was noted. We hoped in this way to find out whether the subject would complete the sentence in terms that would make sense even though the stimulus did not give him reason to do so. (We consider in the following the basis for accepting any content irrespective of its place on the card.)

(2) Results and Conclusions

Cases with no alternative.—There were in all twenty-six judgments returned by subject C. Of these, ten were instances where the content that suggested itself was accepted without any conflict occurring. In all of them the accepted words and letters were articulated immediately and spontaneously as the shutter went down. Generally there was also a visual image present, either good and clear or a blur in which certain characters could be distinguished. When the latter was true, the decisions were doubtful. Subject L. worked in forty-six tests. In thirty of

these, only one alternative presented itself. These came in both articulatory and visual terms. As contrasted with the rule for subject C., the promptness with which they appeared had no influence one way or the other. The visual images present characteristics much like those reported by S. in the former series. It often happened that the image carried over after the shutter had fallen was only a blur and that L. then articulated something that suggested itself and the image cleared up. It would perhaps be better to say that the image of the content placed itself over the blur as the latter persisted underneath.

Cases with No Conflict where the Suggestion Was Rejected.—This happened five times with subject L. and nine times with subject C. The basis of the rejection was as follows: 1) the words or letters did not suggest themselves promptly (4 cases C). 2) Character of the visual blur. On three occasions, C, rejected words that were not compatible with the visual images aroused. The images represented blurs only, but in these blurs there were certain characters such as letters or spaces, that made the acceptance of the suggested word impossible. Once with subject L., the initial length of the blur precluded the suggested content. 3. When the visual image faded right back into the blur, L. gave it no credence. This occurred but once. 4. Two images were judged to be constructs, which for L. were characterized by a lighter faced type than that appearing in the images where the content was judged to represent the percept. 5. L. rejected one suggestion for the outlying member which did not make sense with the rest of the sentence. On the other hand, where a meaningful suggestion for the same position appeared in one instance, C. said that he was afraid that it might be due to the desire to make sense and as he had no visual image to assist him in the matter, he was rather skeptical. This is not, however, a bona fide rejection.

Cases Where there Were Conflicts.—C. reported eight such instances and L. eleven. The criteria used in choosing between the alternatives were: 1. Relative assertiveness of the visual images. 2. The length of the visual blur and failure to fit in with the letters that could be made out in it on the part of the rejected units and agreement with them on the part of the

accepted units. (C. and L.) 3. Visual image vs. lack of one. 4. Visual image more clear (outline or Schärfe). (L.) 5. Visual Image more permanent in time. (L.) 6. Visual construct vs. an image in the dark faced type. (L.) 7. No difference in visual image, but the first suggestion accepted (L.). 8. Associate. One case determined by the content of an associate. (C.) We note finally that L. twice judged content old in spite of the construct character of the visual images. However, no alternative in good type appeared. This peculiar character, then, seems to lead either to rejection or to doubt, and always to rejection when an alternative with a good visual image is present. It is hardly necessary to call attention to the fact so often noted that the criteria employed vary with the individual and can easily be subsumed under the principle of habit.

Cases Where the Outlying Word Was Filled In.—C. filled in the outlying word on six occasions and L. on twenty-four. Once, with C., the suggestion consisted merely in one letter which was correct. In four of the five remaining cases the word suggested made sense. One of these four was rejected as it was delayed. L. reported fourteen suggestions which made sense with the rest of the context. Two received no credence for reasons already given. We see then that in 75 per cent of the accepted words with C. and in 65 per cent with L., the context forced the appearance of meaningful or rather congruous material. When we consider that none of these judgments were correct, we can see how great is the influence of context.

Conclusion.—We find here nothing different from what we have already noted in earlier experimental series, except that we obtain strong additional proof of the fact that what we accept as a valid representation of the past is strongly influenced by its congruency with other matters which we have already come to regard as valid. This is to say that we tend to recall material which harmonizes on the meaning side with the other things that we know about the situation.

IX. EXPERIMENTAL SERIES VII. MEMORY AND IMAGINATION IMAGES

(1) Technique

The object of this experiment was to observe the differences between images of the imagination and of memory when they are aroused in response to verbal stimuli. As has already been pointed out we desired to employ a technique that would admit of the realization of the following two conditions:

1. In the material presented, we shall alter one relation at a time. The subject will have his attention clearly drawn to it, and hence will be concerned with it and not with the unaltered phases. Also the relation will be so vital and its violation so flagrant, that we shall have extreme cases of novelty. Paralleling this we shall use highly familiar content as the basis for the memory images. In this way we hoped to realize the novelty or oldness of a specific relation of two terms, which is, as we have already mentioned, the true object of a recognitive reaction.

2. We shall avoid all stock content of the imagination such as giants, etc. These are really not cases where the subject is judging that the content represents a novel experience, but rather he is conscious that it is something concerning which he has already at some previous time come to the conclusion that it is new. What we really have is the recognition of an old judgment of novelty, and not a true case of altered content.

Our method, then, was as follows. The subject was seated in front of a table, with his back to the window. The experimenter told him to assume an easy position and to visualize in any way he desired (eyes open or closed, etc.) each of the following pairs of objects or of persons, taking careful note of points of difference between the visual images as they appeared. In the early tests, the suggestion was made that the subject should visualize the two different contents alternatingly a number of times, in order to observe the differences. This was not, however,

insisted upon, and was seldom if ever done. By calling for the formation of an image of the imagination and an image of memory in immediate succession, we hoped to be able to throw any differences into the lime light.

In order to insure the presence of bona fide memory images, the stimuli were made highly specific as a general rule, though in a few cases the subject was given some latitude in his choice. This was almost necessitated by demand for variety in objects represented. The experimenter could not specify exactly in every case, for each observer, a particular individual in a given class, and had to allow the subject some free rein.

After the subject reported that he had called out images of each of the required objects or persons, introspections were taken. The following were the aspects considered:

1. Did the image come immediately on the heels of the stimulus word itself, or were there ideas and images of diverse kinds that served as introductory material?

2. How did the image come, spontaneously (without voluntary seeking and effort) or not?

3. What were the properties of the images? Were they clear and distinct (a matter of outline), detailed, stable (hold together in space), permanent (not fleeting), colored, possessed of three dimensions? Did they come as a whole or piecemeal? If the latter, did you voluntarily fill out details which were noted as missing, or did the latter suggest themselves, come spontaneously one after the other?

4. Were there any associations? Mood? Affective Tone? Organic Sensations? Peculiarities of a motor type? Did the image have a background (other than an undifferentiated grayish subjective space)? Was there movement in the image?

5. Did you find any elementary feeling of familiarity? (It was clearly explained that by this was meant an element of the structuralistic type, unanalyzable into any simpler components.) Does the image represent anything that you have experienced before?

The object of the last part of the last question was to assure the experimenter that any given image that he had intended to

function as such, really was an image of imagination. The possibility of seeing many peculiar combinations of animal forms, etc., in books, cartoons, etc., is so great that there was no a priori guarantee that the subject had not actually at some time seen a picture of the content called for by the stimulus word. By asking in every instance for a definite classification of the image by the subject it was the purpose of the experimenter to eliminate this source of error.

Emphasis was placed on the question of the presence of a feeling of familiarity. Under the present conditions, if anywhere, it ought to be noticeable. When we are dealing with sensory material the reactions of an organic nature, etc. set up by the stimulus may be so strong as to overshadow the feeling of familiarity. In a case like the present, where the attention is more specifically directed inward, we ought to be able to isolate the content in question. Moreover, the juxtaposition of the old and the new should throw the specific and peculiar tonus of each into sharp relief if any such tonus exists. The following is the list of stimuli used. It will be noted that the order in which the old and the new images were called for was different at different times. This was done in order to avoid as far as possible stereotyped procedure.

1) XX (a university hall); a horse in the lecture room. 2) Dr. Z.; Dr. M. twelve feet tall. 3) An elephant ;A camel with an elephant's trunk. 4) Two friends, one with the skin of a negro. 5) RR (a university building) standing on end; ZZ (a different building). 6) Flock of flying dogs; flock of flying geese. 7) Cat as big as XX; A dog that you know. 8) An Ithaca street car; A steamboat upside down on top of the water. 9) R (a man) on the top of a tree; A woman of your acquaintance. 10) A bunch of violets: A girl with violet colored hair. 11) A cow's head; A cat with horns. 12) Your home standing on the chimney; A certain building. 13) XXbright red; CC (another building). 14) Dr. Z.'s desk as big as this room; Your seat in the lecture hall. 15) A pair of violet colored shoes; A white dress. 16) Pansies growing in a snow bank; A flower garden of your acquaintance. 17) A mouse with a lion's head;

a rabbit. 18) A grocery store with hardware in the window; a known grocery store. 19) A tree with a red trunk; A tree. 20) Your fountain pen; A pen in the point of a dagger. 21) Your student lamp upsidedown on the table and lighted; A revolver. 22) A tree standing upright in a rowboat; Your room. 23) A horse standing on his head; A particular chair. 24) The book you were reading last night; A strawberry as big as a bushel basket. 25) The library without any tower; Your notebook.

There are, it will be noted, some instances where the subject was allowed to pick out a particular individual of a class himself. This was perfectly legitimate as we were only interested in the image and cared not how the stimulus that aroused it was defined. We employed but twenty-five pairs as the results were uniform enough to make more tests mere drudgery. Especially was it noticeable that toward the end of the series the subjects would dismiss the matter with the statement that the results were as usual.

The experiments here reported were performed at Cornell. The writer wishes to express his appreciation of the kindness and courtesy of the members of the Psychology department of that University for affording him every opportunity to complete the work started at Chicago. The subjects were Miss Curtis and Mr. Bishop, graduate students in psychology, and Mr. Boring, an instructor in the department.

(2) Results

We summarize the results as follows:

1. *Mode of entrance.* With a few exceptions, the manner in which the image came differed in the products of memory and those of the imagination. The memory images came immediately and spontaneously in response to the stimulus. As Bh. (Bishop) said, their appearance was automatic. In the case of C. and of Bh., they came as a whole; *i.e.*, they were complete in detail on arrival. This latter point is of course one that involves a rather subtle question. What do you mean by completeness of detail? Almost all images are fragmentary as compared to

percepts, and moreover there is no percept of the object present, with which we can institute a comparison to see whether anything has been omitted. Again, we cannot score the number of details present and say that one image is more complete than the other in a quantitative sense. The definition was then adopted that an image was detailed when the subject was not conscious of any missing items, the absence of which attracted his attention. Such an image was subjectively complete. In contrast to this mode of entrance of the memory image, we find that as a general rule the imagination image was built up voluntarily. The familiar constituent parts appeared at first in isolation, and the subject put them together. When it was a matter of altering the size, the subject got the content in its normal proportions at first and then proceeded to make it grow. We have a volitional process involved, the images constituted as the result of directed effort over and above that involved, of course, in the mere initial undertaking of the problem. With Bo. there was, it is true, some effort involved with memory images in filling out details which were not present at first, but this is different from the above. The point is, namely, that in the case of memory images, the subject already has a content which he feels to be in some sense adequate to the instructions and then fills in details. This does not involve persistent strain and voluntary effort, but merely a little here and there as occasion demands. In the case of the imagination, the whole matter is an effortful process and there was no quasi-adequate nucleus to work on. Rather the latter had to be built up gradually.

2. *Stability.* Another peculiarity that occurred frequently with imagination images was their lack of stability. The parts would not stay together in space, or the image tended to revert to its old proportions. C. said that there was continual effort involved in maintaining the matter in its desired status. This did not always occur. It was, however, the general rule in Bh.'s reports, it was noted in fifteen cases with C., but it was relatively rare with Bo. On the other hand, without exception memory images were stable, *i.e.,* had no tendency to disintegrate in space.

3. *Paucity of detail.* On a number of occasions with Bo.,

the imagination image came quickly and easily. Some of these images were characterized by lack of stability, as noted above. Another basis of differentiation is the paucity of detail, by which we mean felt lack of detail (as explained). This generally comes about as follows: The initial familiar content out of which the memory image is built up is fairly detailed. On subsequent manipulations, however, many of these items disappear. This reduction of content may go so far that the results are characterized as being mere blurs, or cease to bear any resemblance to what the subject is trying to call out. Bo. also declared that he was unable to restore the concreteness by voluntary manipulation.

4. *Lack of Permanency.* Bh. reported instances where the imagination image was there once and gone forever, no effort being effective in recalling it. It is undoubtedly true that memory images were not always permanent, as they often faded out quickly but they could always be revived. With Bo. all memory images stayed as long as he wanted them. They were, so to speak, voluntarily relinquished. Of one imagination image, however, the subject said that it kept disappearing against his will and that he could only recover it with difficulty.

5. *Color.* Color is a rare thing in imagination images with Bh., while almost all memory images are possessed of it. No difference in this aspect is found with the other subjects.

6. *Size.* We have a peculiar phenomenon reported by Bo. in connection with three imagination images. In two of these, parts of the novel complex were felt to be distinctly out of proportion. The head of a man was too large, etc. In the third case, where the images were of extended landscapes, the memory image required eye movement to look it over and take in different parts, while the imagination image fell, as a whole, within the field of clearest vision. It was, then, felt to be disproportionately small.

7. *Three dimensions.* Bo. reported that three imagination images were flat. All other images were in three dimensional space.

8. *Motor Phenomena.* C. reported differences in the motor

reaction set up. She often spoke of an attitude of going out towards memory images, while with the imagination images there was often an attitude in the hands and arms of forcing the images which would not stay together in space to come closer together. When the normal space relations were violated (building on end etc.), there was a feeling of twisting some part of the body.

9. *Qualitative Difference.* Twice Bh. reported what may have been a qualitative difference. The terms employed were "filmy" and "vaporous," as applied to imaginary complexes.

10. *Eye Movement.* Although this experiment was not especially designated to test the presence of eye movement, and although we are thoroughly conscious of the fact that the subject is especially liable to suffer from illusions in regard to this matter, we note a few rather interesting observations. We are perfectly aware that they are not irreproachable. Twice with imagination images C. reported eye movement, Bo. records eye movement or eye strain with all but three of the imagination images. They formed a part of the accompanying kinaesthesis. Eye movement occurred also with the memory images but somewhat less often. It carried the localizing reference, and was concerned in the exploration of the image. These results are contrary to those of Perky.

11. *Organic Sensations.* C. and Bh. reported differences in the organic sensations involved with the two types of images. C. said that the sensations accompanying the familiar images were such as were always present unless an unfamiliar stimulus introduced a complication. On a number of occasions, Bh. reported that the organic sensations were hardly noticeable at all. With Bo. we took very careful introspections on this point. In the case of memory images, the subject spoke of slight feelings of pressurelike pull, of achy, visceral sensations in the region of the diaphragm and aesophagus. These occurred also with a few imagination images when the effort was moderate. On the other hand head-and-neck strains were prominent when there was much effort.

On the basis of these statements, it appears to the experi-

menter highly probable that these organic sensations are not to be looked upon as independent peculiarities differentiating the two types of content. They are rather the results of a relatively easy arousal on the one hand and a relatively effortful process on the other. This comes out clearly in the introspections of C. and of Bo. With the former, only the imagination images, involving effort, are the occasion for the appearance of organic sensations different from those of normal life. With Bo., as we have already said, the sensations involved are given similar description, except where there is a large amount of effort present. This is easily understood. Effort and hindrance would naturally be the cause of many currents being sent down into the visceral system, and also into the muscalature of the head, neck and shoulders, such as is usually involved in attention, and this would result in a decidedly different background in the two cases.

12. *Affective tone.* The contention that affective tones of a particular type are the usual accompaniments of different kinds of images is not substantiated by our results. C. reported that normally the memory image is accompanied by pleasantness. The majority of cases of imagination were neutral, though both pleasantness and unpleasantness sometimes occur. With Bh., affective tones are an exception. When they are present, the same rule holds. With Bo., on the other hand, we found affective processes of both kinds in both types of images. (Bo. was somewhat sceptical of his ability to isolate pleasantness—unpleasantness components at any time whatsoever. As far as he ever is able to find any such elements in his consciousness, he said that the above would represent the present situation.)

13. *Associations.* Associations occurred with both memory and imagination images in the reports of C. and Bh. This seems to constitute a difference between the recognitive process on the ideational and the sensory levels. In our work with the latter, we noted that associations were accompaniments of old content as a general rule or at least that some differentiation on the basis of immediacy of appearance was possible. The difference in the results is easily explained when we consider the two situ-

ations. When dealing with sensational content, the attention can turn away to something else, provided no threads of associations are found to radiate from the stimulus. With the image, on the other hand, the conditions of the experiment are such that it is made the focal point and the center of operation. The mind dwells on it as the result of the instructions and the effort to manipulate the content. Consequently associates are bound to appear. For there is no content about which we cannot think something, in which relations of similarity to other experiences are not observable. The notable fact is that in spite of being deprived of this criterion, the other points of difference give us a method of distinguishing the two phenomena.

There is one other point worthy of note, the rarity of movement in visual images. We found it but six times. It is not limited to either type of image.

14. *Feeling of Familiarity.* We are unable to find any such thing as an elementary feeling of familiarity. C. and Bh. could isolate nothing except the differences in organic sensations already reported. Bo. was more conservative in this matter, but at no time could find any elementary feeling of familiarity. He once or twice said that he could not be sure that there was nothing present except organics; but on the other hand, he often denied the existence, as far as his introspections went, of any such element. Nor were organics present at all times. We found in a number of instances that Bo. denied the presence of either organic sensations or feeling tone and reduced the whole matter to cognitive reference. We already pointed out that our present mode of procedure was especially adapted for studying the feeling of familiarity if it existed, and hence our conclusions in this matter assume even more weight in our eyes. When we consider that in the overwhelming majority of cases of perceptual recognition, no organic sensations were present, we must come to the conclusion that a so-called feeling of familiarity rarely if ever played any part in the results. We firmly believe that those authors who have spoken of a feeling of familiarity have failed to differentiate between psychological content and meaning. What we really have is a consciousness that we have

or have not seen a percept before, or that an image does or does not refer to previous experience, and that this is a consciousness of reference, a meaning, and not a bit of existing content.

(3) Conclusions

We are then unable to substantiate in any way the position arrived at by Perky. As far as our evidence goes (and in the case of Bo. it is of a good deal of weight), eye movement occurs with imagination images as well as memory images. Surprise is in no sense the mood habitually accompanying imagination images. The feeling of familiarity is no more from a structural point of view than a peculiar organic background plus the meaning that the content represents or refers to a past perceptual experience or experiences, or the meaning that it does not do this. The images of imagination are often unstable, are less likely to be colored with some subjects (Bh.) and are more fleeting than images of memory (when there is any difference here). There is no evidence of organic empathy or of imitative movement. Images of the imagination are not more quickly aroused, suddenly and as a whole, but rather involve delay, effort and continued directive control by the subject. They are not less changeable than images of memory, but more so, when any difference exists. There is no observable tendency for the memory images habitually to stir up associations, but they often do. The imaginary products also do the same. It is of course a question how far our results are strictly comparable with those of Perky. The criterion of differentiation that we employed was that with memory images the subject was conscious that he had experience either that particular individual represented or objects of the same general class, while in imagination the image represents something which has never had a counterpart in his perceptual world. This involves the personal reference of Perky. The specific localization in time and space is, however, not called for. As a result, it is entirely possible that we are not dealing with the same thing.

In contrast, however, to the results reported by Martin and Ogden, whose criteria are quite similar to our own, we find

certain well defined differences to exist in the two types of images over and above the difference in meaning. Some of these differences are common to all our subjects; others vary from individual to individual. Moreover the same differentia are not always present. The point is that *some* difference is always observable. The following is a list of differences. The first four are common to all subjects. With the remainder we have indicated the subject reporting the factor.

Imagination Images	Memory Images
Effort and difficulty of arousal	Ease of arousal
Delay of arousal	Immediacy of arousal
Instability in space	Stability in space
Permanency when desired	A tendency to fade out against the will of the subject
Lack of color	Color (Bh.)
Lack of proper proportion	Correct proportion (Bo.)
Lack of three dimensions between parts	Three dimensional character (Bo.)
Filmy and vaporous character	Clear cut and distinct (Bh.)
Difference in the motor reaction (C.)	

An examination of these factors indicates clearly that the characteristics of the imagination image are those normally accompanying content where habitual relations do not exist, or better where they are being established. There is less of a concrete, perceptual character, absence of color, or three dimensions, or a filmy tone. The images do not appear automatically and quickly and without effort. In fact they exhibit many of the properties of reactions which have not yet been thoroughly automatized. On the other hand, memory images partake of the general pattern of habitual reactions. The automatic character and the approach to the characteristics of perceptually present content is striking all the way through. In closing, we note once more that individual variations exist.

X. SUPPLEMENT TO EXPERIMENT VII

In the course in qualitative experimental Psychology in the Chicago laboratory, the following experiment has been given for the last three years.

Directions. In the exercises are given pairs of objects: one a customary or memory object, and the other a novel or imaginary object. The experimenter picks some pair and requires the subject to visualize as vividly as possible the two objects a number of times in alternation. The subject compares and reports as to all differences in the character and behavior of the two visual images. Note such things as ease and quickness of arousal, stability and persistence after arousal, emotional attitudes involved, tendency to arouse supplementary strains of thought, etc. Experimenter secures introspective records for fifteen pairs chosen at random from the list. From these records generalize as to any constant subjective differences between the two functions upon which one's discrimination between them may be based.

The character of the pairs used is highly similar to those of our test. We give below the reports obtained from four of the more careful introspectors, in this year's class, (spring, 1914). These records were selected by the instructor in charge.

Subject	*East and quickness of arousal*	*Stability*	*Persist*	*Emot.*	*Assoc.*
G	M yes I no	I no		M yes I very few	M yes
C	M yes I less		M yes I no	M yes	M yes
D	M yes I less	M yes I less		M pleasant I often unpl.	M yes I yes
R	M yes I less	M yes I less		M Pl. I 66⅔% 33% unpl.	M yes

Again we find that memory images are more easily aroused, are more stable, and sometimes more persistent. The associations appear more uniformly with memory images, though some are noted by D. with imaginary products. Both G. and D. speak of the tendency for memory images to come as wholes, while imagination images are built up gradually from familiar nuclei. G. in addition reports that he was practically unable to visualize certain of the novel complexes at all. D. and R., who took note of the affective tone, report more pleasant reactions with memory. Still pleasantness was noted with imagination products also. R. was explicit in his statement (voluntarily offered) that the unpleasantness of the latter was due to the effort involved. Professor Carr tells me that these selected results are typical of the usual reports of all classes.

XI. GENERAL CONCLUSIONS

As a result of our experiments, we reach the following conclusions regarding the phenomenon of recognition:

Recognition on its meaning side (the *what* the subject is aware of) is the name applied to one of the two ways in which objects may be cognized from the point of view of their relation to the individual's past. Any stimulus may be classified as old or new, and this classification is a meaning or cognitive distinction on a par with numberless other meaning distinctions. Each of these reactions is a positive thing, neither one consisting in the mere absence of the other. The term re-cognition indicates that the stimulus is cognized as old, not that there is a unique process involved which is in no way related to any other psychological phenomena. Judgments concerning the oldness or newness of any content refer to one or a number of specified relations betweeen terms. The terms themselves are generally familiar. Even when dealing with memory and imagination images we must accept the truth of this statement. As a general rule we have no interest in the image itself. Rather it is classified as a product of memory or of the imagination in so far as it represents a relation that has been perceptually experienced in the past or which has had no such counterpart. The present image is the way we represent to ourselves and its peculiarities are (as we have seen) criteria by means of which we decide concerning the oldness or newness of relations which are being, at least tentatively referred to the past content of perceptual experience. The image is the means by which we think the relations and the terms. In some few instances, of course, the earlier experience with relation to which the present image is being classed, is itself an image. The question is, not does the present image represent a past percept, but does it represent an earlier imaginal complex. This happens but rarely, and is a phenomenon that forms no exception to the statements made

above. The only difference is that the past object with which the subject is concerned is ideational. We may then conclude that in the case of perceptual recognition we judge that an objectively existing relation is or is not altered while in the case of recognition on the ideational level, we judge that a represented relation is or is not altered. In both instances the meaning may be mediated by images, or it may be mediated by sensory activities. It is then a question of whether the perceptual object of the judgments is present or not, not of any fundamental difference in the meaning character of the reaction in both perceptual and ideational recognition.

We do not deny that additional specifications may be laid down which the object must fulfill such as a reference to a definite time and place, but these are not necessary to recognition as such. They are further refinements within the larger area and make the qualification more definite. This personal reference, although always present, need not be explicitly formulated in the subject's consciousness. He may for instance say "I know that man." Here no overt declaration of previous experience is contained, but it is self-evident that it is implied. But the judgment "I have seen that man," expresses the relationship explicitly. This personal reference, the awareness of pastness or of novelty with regard to personal experience is the minimum meaning that is necessarily involved. The fact of this meaning, the fact that a present content can transcend itself, can refer to the past, is an ultimate. This statement does not overlook the fact that the cognitive distinction is mediated by content differences, or that (as we shall see) the relationship between these two phases (content and meaning) is probably due to experience. In this sense, of course, the phenomenon is not ultimate. But that the mind should, even on the basis of experience, be conscious of its past, that it should possess the power of fathoming the meaning of the criteria which present themselves, and of judging with reference to a situation which is no longer present, this is one of the unanalyzable givens of psychological science. In fact, it seems highly probable, that some at least, of those who have defended the doctrine of an

unanalyzable and ultimate and hence unmediated recognitive reaction, have really been concerned with this transcendent phase of meaning exclusively.

Although we conceive of the cognition of pastness and of novelty as an unanalyzable datum of the conscious life, our results are opposed to any doctrine which would maintain that these distinctions are not mediated by peculiarities of present content. We have found that there are differences in the manner in which this mediation takes place and have been able to arrange the judgments returned under distinct headings on this basis.

The subject may or may not be conscious of the fact that such mediation has taken place, or even when he realizes that this has occurred he may be unable to isolate the particular phase of the content that is concerned. He can never know directly of the mediation when the perceptual content itself is the sole basis for the reaction. This is, as we have pointed out earlier, due to its given and unyielding character. Provided no additional elements of content are brought into play, an object, presented from without is the same stimulus characterized by the same qualities and relations (of a type which can be noted at the present moment) for the man who has seen it earlier as for him who has not. Under these conditions, even though the stimulus be the guide for the cognitive classification, all that the subject knows is that he reacts to it, but he can only justify himself by saying that he believes his judgment to be correct. He cannot point out any reason for his judgment beyond the faith in its trustworthiness. With factors of content other than the percept, the subject may or may not realize at the time that they are guiding his decision. He may say "Here is a visual image, therefore this is old," or he may judge the stimulus old, unconscious of the rôle of the image. The more habitually criteria are employed, the more likely they are to escape notice. This will account for many grounds for the old-new cognitions being overlooked. Then again, as we shall see, many of these criteria are relative matters, which are everywhere difficult to isolate.

Returning to the differences in the manner in which this

mediation takes place, we found that with many judgments the meaning is attached to the perceptual content directly, *i.e.* there are no peculiarities of structure outside of those involved in the perceptual content itself, which are found accompanying the consciousness of reference. The characteristic thing about these judgments is that they come immediately and are felt by the subject to be unquestionably correct. We have two reasons for believing that we have here truly mediated decisions. In the first place the correlation between unaltered perceptions and old reference, and altered percepts and cognitions of novelty is very great. This is to say that the judgments are generally correct, the perceptual content and the meaning standing in one to one relationship. If there is no true mediation, how can this be accounted for? In the second place, we find that where the judgments did not appear immediately, where, therefore, the percept was unable to produce a reaction, and a period of doubt succeeded unrelieved by ideational criteria, the content was normally classed as new and the judgments were incorrect in over 50 per cent of the cases. When an appeal to content other than the percept is made, and this is not rewarded by the appearance of definite criteria, the subject will regard absence itself as a criterion of novelty and will be misled. They are bound to choose some criteria good or bad. But with the judgments where we believe the stimulus itself to control the reaction, there is a great degree of correctness observed and the old and new responses are approximately equal. There is some reliable guide both for novelty, and past reference. What besides the percept can furnish it? The advocates of unmediated consciousness of reference can find no comfort in these cases. A priori we see no reason why perceptual content may not guide cognitive reactions, and in this instance we are convinced that this is the true explanation of the phenomenon under discussion. Also the only argument against the doctrine is the absence of any sense of mediation and this is fallacious.

These judgments mediated by the objective stimulus itself represent we believe those cases where the habitual character of the old content and where the non-habitual character of the al-

tered stimulus is most strongly felt. Our belief that this is so is justified by the facts, (1) that the judgments come immediately (2) that the subject is so sure of his answers. The status of the situation is so marked that the subject never appeals to more reflective criteria, never hesitates about his reply, and never thinks of the possibility of error. Where old content then, for any reason whatsoever, has made a deep impression or new content is decidedly out of harmony with the subject's general memory of the past, the percept itself is sufficient to bring home the fact.

On the other hand, it often happens that the perceptual content itself is not able to mediate the cognitive distinction. Doubt characterizes all such judgments. Under these conditions we have found that the differences in meaning are paralleled by differences in content other than those involved in the stimulus. This is always true in recall (no percept present) and in cases where visual images of imagination or of memory are concerned. The content side seldom if ever consists in a peculiar structural element, a feeling of familiarity or strangeness. If we confine ourselves for the present to judgments concerning percepts, the criteria may be classed as positive or negative. By positive criteria we understand concrete phases of the conscious pattern which serve to guide the subject in his reaction. Such are: (1) A motor clinch or tendency to go out towards old content and a feeling of withdrawal with new; (2) certain moods, which are very rare and are practically always correlated with other more significant criteria (a feeling of familiarity is not here included); (3) visual images which furnish a number of modes of differentiation among which we call attention to (a) mere appearance; (b) stability vs. instability in space; (c) locus in space, old content appearing where it was formerly seen, new where the re-presented series is exposed; (d) the appearance of a partner different from the one re-presented with an individual; (e) quality, a visual image of the stimulus was useless, one representing a different combination led to a judgment of novelty; (f) immediacy in arousal, an image of the presented content which came immediately was accepted, while a delayed image

was useless; (g) failure to submit to manipulation led to a judgment of novelty; (h) mode of entrance, images coming in piecemeal and not as a whole, led to a rejection of the content they represented; (i) an artifact character which led to the rejection of the content imaged; (j) the relative completeness, permanency, and persistency of the images of possible alternatives; (4) associations which furnish the following basis of judgment, (a) mere appearance resulting in judgments in accordance with their implications; (b) immediacy, immediate associates leading to the acceptance of the content with which they appeared, delay resulting in a judgment of novelty; (c) quality, the names of geometric forms and of colors are useless; (d) in cases of conflict, the association leading to a long line of subsequent ideas triumphed; (5) rhythm; (6) relative strength of motor reactions; (7) relative ease of articulation; (8) tendency to attract the attention. This constitutes a complete list of the positive criteria used when the subject was forced to decide concerning the oldness or newness of perceptually presented content. No subject used more than a few of them and the same subject often used different ones with the different problems, known vs. unknown series, and different alterations.

As opposed to these positive criteria, we distinguished so-called negative criteria. Stimuli which failed to arouse associations, visual images, or any of the positive types of content were judged new. A few exceptions were noted, the subject looking upon some objects unaccompanied by the above as old. We have given reasons for believing that in these instances one of three explanations will be found to apply: (1) The observer failed to note positive criteria of the types enumerated; (2) he failed to isolate unusual bases of judgment which our concepts were not of assistance in calling to his attention; or (3) he disregarded the usual implication of the isolation of the percept, being well aware that a negative criterion was not very reliable, but often resulted in an erroneous reaction. Unlike the positive criteria, the negative were found to be used by all subjects.

We have already repeatedly pointed out that these criteria,

positive and negative, may be looked upon as embodying the working of the principle of habit. Those leading to judgments of old are characterized by properties which we would anticipate with habitual relations between content, while those conducive to judgments of novelty show the pattern of habit violation.

Invariable concomitant variation always indicates some kind of a causal connection between the factors involved. The exact nature of the relationship is, however, not so easily determined. We cannot say which of the variables is the cause of the other, unless there is a highly unambiguous relation of temporal succession observed, nor can we be sure that they are not both effects of some deeper lying single cause. Especially is the problem difficult where we are dealing, as here, with phenomena whose temporal relations are seldom clear, and which are so subtle and hard to grasp. We are then frankly unable to assert in any dogmatic manner that the peculiarities of structure which we have established are the causes of the judgments returned and not vice versa. We have previously set forth a number of reasons that inclined us to this view, and we note but three of them at this point. In the first place, it is hard to believe that the mind which exhibits such a tendency to economy, carries around a whole lot of useless material. Why, if the structural differences are really superfluous, do we not have unmediated meaning under all circumstances?

In the second place, the fact that in many cases the subject looked upon these content differences as mediating the judgments is of some value. It is undoubtedly true that the observer is sometimes mistaken as to the stimulus responded to. Generally he must be regarded as knowing the real condition of affairs, especially when a large number of subjects pick out the same elements of content. In the third place, the so-called criteria were observed in cases of doubt, while when the decisions were very certain, they were often lacking. Does this not seem to suggest a relationship between their appearance and the obvious need for aid in meeting a difficulty?

We have enumerated the criteria employed in perceptual rec-

ognition, *i.e.*, in judgments where the object cognized is present to sense. These cases differ from recall in that in the latter, no hard unyielding content is given from without. The subject must summon the idea (or perception) which represents the earlier experience. He not only accepts what he judges to be old, he must first find what he is to accept. This difference admits of a number of new factors, such as order of appearance, ease of arousal, etc., which we might expect to furnish grounds for deciding what the earlier experience actually was. We give below a list of the criteria we found operative in guiding recall: (1) Mere appearance of a single possibility led to its acceptance; (2) relative assertiveness of the visual images of possibilities; (3) the arousal of associated visual images representing the earlier circumstances; (4) primacy in time; (5) relative assertiveness of the idea, however carried; (6) the introduction of associates; (7) ease of articulation; (8) ease vs. difficulty and immediacy vs. delay of arousal; (9) construct characters of the visual image, its length, its fleeting character, its completeness, and its clearness; (10) congruency with a larger context. We note that many of these factors are the same as those concerned with perceptual recognition, and that those which appear here for the first time are such as can be explained as due to the difference in the problems mentioned (primacy in time, ease of arousal, etc.). This substantiates, we believe, our introductory hypothesis that there is no fundamental difference between recognition on the perceptual and ideational levels, in respect to the mediating processes concerned.

Returning now to recognition on the perceptual level, we found in addition to the judgments where the meaning was a function of the percept and to those characterized by doubt and subsequent use of reflective criteria, intermediate cases where there was an initial inclination in one direction or the other. These were obtained by shortening the time interval between the successive presentations. They differ from the first judgments in that these involve no subsequent appeal to criteria while in these intermediate instances such an appeal is usually necessary, and from judgments of the second class in that the

initial inclination is normally correct. With the truly doubtful decisions of the type mentioned earlier, whatever immediate reaction appears is both useless and unreliable. We have thus a gradation from cases where doubt and a subsequent decision owing to peculiarities of content are found, up through cases where an initial inclination is subsequently verified, to instances where the meaning is a function of the percept itself. This phenomenon reminds one of the characteristics of habit in other fields. In motor learning for instance as the process nears perfection, the conscious control becomes less and less. In our work, the more deeply content is impressed at the time of the earlier presentation, the more the meaning distinction tends to be a part of the perceptual "Auffassung" itself, allowing the subject to dispense with an appeal to more reflective aids.

In addition we note three points which we believe our experiments establish. (1) In recall, the congruency with a larger context has a decided influence in determining what the subject will accept as a representation of the past. (2) The same general criteria are employed where the subject has no opportunity to work over a stimulus in a highly reflective manner as when he may do so. The bearing of this on all arguments for an ultimate consciousness of reference based on experiments with distractions is obvious. (3) Visual memory and imagination images are distinguished by certain peculiarities, the list of which appears on page .

We have thus substantiated the following assumptions with which we entered the work, (1) the existence of a parallelism between meaning and content; (2) the differences of content underlying the judgments are such as we would expect to find if we assume that the habitual and non-habitual characters of old and new should respectively find expression in peculiarities of structure; (3) the cognition of oldness and the cognition of newness are both positive things and are in every way similar processes; (4) the cognition of oldness and newness on ideational and perceptual levels is in most respects one phenomenon. Moreover, the technique employed involving (1) an appeal to doubtful cases and striking violations of habitual relations, (2) reliance not entirely on the subject's own introspections but on

concomitant variations, and (3) the varying of but one relation at a time, which can be indicated to the subject, has justified itself. No other means would have admitted of a truly reliable study.

The question now arises, how do the particular characteristics of content cited come to be correlated with the meaning differences. We have already pointed out that the fact of past reference is ultimate and that on the other hand these reference values are probably due to structural criteria. How do these two phases ever get woven together. We would answer, "in the give and take of experience." This does not imply for a moment, that we have first bits of content and then attach meanings to them. All content has some kind of meaning from the beginning, *i.e.,* it tends to set up reactions even though they be purely motor and uncoördinated. We know that children are relatively unable to distinguish the products of their imagination from those of their concrete experience.[1] Moreover, as the work of C. and W. Stein[2] has shown, conscious recognition of persons, while it appears early, is uncertain during the first years. Also recognition after an interval of a number of weeks is not noted until the end of the first year. But we know that long prior to this, the child can react to repeated stimuli or similar stimuli in the manner that he has learned by the trial and error method. In the course of experience, he must inevitably find that even among similar objects there are differences in the success of his reactions. All men do not respond like his father and all dogs are not his friends. In the grim school of experience then he must gradually come to a hazy awareness of the difference between old and new. And the same is true of imaginary objects. His trip to the moon when regarded as fact does not lead to anticipated results. The capacity for making this distinction on the basis of experience we must accept as ultimate, but how it comes to function seems fairly clear. Now accompanying these failures and successes when the child proceeds as though most ideas were memories and all like

[1] Meumann, Vorlesungen, I, 2nd edition, 1911, p. 518.
[2] *Ibid.*, 433.

stimuli old, there are, we believe, differences in content. And these differences of content gradually come to guide the child in his distinctions on the meaning side. This is not brought about in a *discriminating* manner any more than the rat picks out certain phases of the situation and consciously reacts to them. But by a method of trial and error, some structural properties when present admitting of successful habitual reactions while others if met in the same way lead to unpleasant consequences, association by contiguity establishes the relationship between such factors and a classification with respect to oldness or newness. That there is such a growth in the power of correct cognition is attested by the fact that the child only gradually distinguishes between memory and imagination. And that the correlation is established blindly, so to speak, seems to follow from the fact that even in adult life the subject cannot always isolate the criteria which he is using. Witness also the many theories of recognition that have been propounded.

This explanation of the manner in which certain structural peculiarities come to carry past reference renders intelligible the use of different criteria by different subjects, and by the same subject when dealing with different problems, and the fact that he is not consciously aware of the criteria on many occasions. It is easily understood that diverse factors come to be correlated with differences in meaning in the course of the experience of individuals. The give and take of life will emphasize different aspects of the content with the observers and with the divergent tasks presented by the problems in hand. And from this the cases where the criteria are disregarded may be understood. As the correlation is set up in experience and is brought about more or less unconsciously, we can well comprehend that it is never complete and perfect. The individual is constantly tending to overlook the dictates of his experience. One cause of this lies in the nature of the criteria themselves. They are modes of behavior, immediacy of arousal, stability, etc. Such distinctions are of course always highly relative. Hence the subject may react to a relatively immediate experience as though it were moderately delayed and later report that it was immediate. As a result, we record an exception.

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Formal Discipline from the Standpoint of Experimental Psychology

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PREFATORY NOTE

The writer was driven into this problem some years ago through reaction to instruction he was then receiving in education. He owes a debt of gratitude to those men who so faithfully and painstakingly retailed the newest notions culled from heretical theory or hatched from the early and somewhat hasty laboratory work. Interest was more fundamental in school training, in those days, than attention, suggestibility than obedience, and vocational training than mental training. Sherrington's 'spinal dog'[1] had not yet removed by the skillful use of its scratch-reflex, the 'reflex-arc' from the vertebrate nervous system, and it was supposed that we had been endowed with a mechanism by which reactions to stimuli could be literally 'specific'; school training consisted in 'specific discipline,' which was hysterically opposed to 'formal discipline.' Nor had the "All or None" principle of the terrapin heart,[2] yet suggested for mental development the efficacy of strenuous innervation; training needed no spur but interest. Generous acknowledgment of all those incentives is hereby recorded; without them this investigation would not have been made.

The writer is under many other obligations: First and foremost to the Head of the Department of Psychology, Dr. F. Angell, whose courteous extension of laboratory facilities and whose encouragement, advice, and assistance, have put the writer hopelessly in debt; to Professor Lillien J. Martin, for kindly interest and helpful suggestions; to Miss Ruth Adele Sampson for valued assistance in the correction of the manuscript; and to the following groups, almost wholly of fellow-students, who cheerfully and faithfully performed the onerous yet indispensable offices of reagents; those whose names are starred underwent periods of arduous training besides taking the tests:

[1] Sherrington: Integrative action of the nervous system. 1906. Ch. IV.
[2] Stiles: Am. Phys. Ed., 1910, 15: 1-5.

In the experiments on Word-Marking and Weight-Lifting:
*Mr. Geo. Snow-Gibbs.

In the experiment on Discrimination:
*Mr. G. Altnow,
*Mr. T. Nakamura,
*Mr. K. Yasuda,
Miss Bernice C. Rowell,
Miss Bonnye Anderson,
Miss Gertrude B. Weaver.

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Miss Rowena C. Bush,
Miss Luella E. Behrens,
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Miss Ruth Cain,
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In the experiment on Attention:
*Miss Christine Madison,
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*Mr. Joel A. Snell,
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Miss Maud H. Bassett,
Miss Nina E. Moise,
Mr. Geo. L. Righter,
Mr. Charles L. Allen,
Mr. Asa C. Dimon,
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Mr. Stanley M. Reeve,
Mr. Lloyd I. Tilton,
Mr. Alexander Davis,
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Mr. Zeb. A. Terry,
Mr. Robert W. Wilcox.

In the experiment on Reproduction:
*Miss Alma Holmes,
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Miss Susan M. Toy,
Miss Mabel I. Clark,
Miss M. Dorothy Parkinson,
Miss Nellie Allen,
Miss Mabel B. Angell,
Miss Ruth Hutchinson,
Mr. Harold A. Hughes,
Mr. William H. Bloeser,
Mr. E. Leib,
Mr. Earl T. Dutton,
Mr. Herbert L. Hubbard.

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PART I

ORIENTATION

I. Introduction

The conception of formal discipline[1] belongs to the philosophy of education, and has dominated the educational theory of the greater institutions of higher learning from their inception to the present day. Twenty years ago it was vigorously assailed, however, by some of our eminent educators[2] who claimed that our schools are suffering under the bonds of this tradition. It was charged that the conception is a myth; that the sole end of study is the information acquired by it; that no subject of study is of greater value than another except upon grounds of adjusting the student directly to his social, economic, industrial, environment. It was explained that the 'Dogma' rests upon the 'faculty psychology' which lies respectably buried under the dust

[1] Formal Culture: (formale Bildung; éducation formelle). The doctrine of the applicability of mental power, however gained, to any department of human activity. This doctrine is used as a standing argument for so-called disciplinary education, especially that in pure mathematics and classical languages. The assumption is that if the student masters these, he will thereby acquire a mental power that can be applied almost equally well to any kind of practical or professional life. This gymnastic theory of education involves the idea that it does not matter upon what the mind is exercised, provided only the exercise be rigorous and long-continued.—DeGarmo in Baldwin's "Dictionary of Philosophy and Psychology."

This expression has been used to indicate the general reaction upon the ability of a student that is by many supposed to spring from the method of study rather than from the content which is learned.—Ernest N. Henderson, in "A Cyclopedia of Education," edited by Paul Monroe. N. Y.: Macm. 1911. P. 642.

[2] *Vid.* Hinsdale, B. A.: The dogma of formal discipline. Proc. N. E. A., 1894, p. 625; also his book "Studies in Education," Ch. 2.

DeGarmo: "On the report of the Committee of Ten." Ed. Rev. 1894, 7:277.

Rein: Outlines of Pedagogics (tr. Van Liew) 1895. P. 61.

DeGarmo: Herbart and the Herbatians. P. 26.

of a century, and that its continued vitality is derived from its momentum in a field in which the 'resistance' of modern experimental psychology is wanting. It is true that the challenge was made by men of 'Herbartian' training, that the formal definitions of the conception were made by them and would not be entirely satisfactory to proponents, and that the Herbartian psychology is equally dead.

Nevertheless, the point in dispute has shifted into psychological territory, and it is for this reason that Experimental Psychology has come in contact with the venerable doctrine.

The psychological question at issue concerns the relations which exist between the various mental processes. According to the 'faculty psychology,' the improvement of observation, or of reasoning, or of memory, or of any of the thirty-five faculties of the mind, in one field of experience was applicable to all other fields of experience; but improvement of one 'faculty' did not affect others. According to the Herbartian psychology, these 'faculties' are abstractions, adding nothing to fact and affording no explanation of mental phenomena;[3] the Idea[4] is the sole real content of the mind and through it alone are mental phenomena unified. Training of the mind is effected through the appropriation of ideas and is limited in its applications to the field of experience to which the ideas belong. Both of these psychologies

[3] Herbart's criticism of the 'faculty theory' lies in the two following objections: (1) 'Faculties' are mere possibilities; there is no sensibility before sensation; (2) they are class-concepts, obtained by a provisional abstraction from the inner experience, and then raised to the rank of fundamental forces of the mind and used for the explanation of our internal processes. Both criticisms are as telling against the established sciences of physics and chemistry as against the 'faculty-theory.' (1) The forces of physics do not exist apart by themselves any more than do the 'faculties,' but only in the phenomena called their effects; (2) they are abstracted from the concrete phenomena and are class-concepts used for the explanation of the phenomena themselves. According to the criticism, there is no gravitation before the falling of the apple, nor can it as a class-concept, be used to explain the fall of the apple.

[4] This Idea, as well as its relations to the emotions, feelings, and impulses, is hypothetical and does not at all square with the facts of inner experience. *Vid.* Wundt: Prin. of Phys. Psychology. (From Ger. Ed. 1893.) Pp. 18ff.

have performed their service in the development of the science and are now of but historical interest. The question, therefore, so far as their authority goes, remains open.

Special observation and investigation have sought to throw some light on the problem:

(1) The contribution of formal school training to success or eminence in practical life has been estimated.[5] (2) The relationship between undergraduate scholarship and preëminence in the graduate schools of law and medicine has been reported,[6] and the standing of our Rhodes scholars has been compared with that of their fellows in Oxford who had followed similar (classical) courses but with more rigorous training.[7] (3) Experimental pedagogy has already contributed a large amount of data concerning the relationship between capacities employed in school work or between school subjects.[8] (4) And the data of Cross-

[5] Halleck: Proc. N. E. A., Dep't of Superintendence. 1906. Pp. 34-41.

Pritchett: Fifth annual report of the President and the Treasurer of the Carnegie Foundation for the advancement of teaching. 1910. P. 56.

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Schuster: The promise of youth and the performance of manhood, a statistical inquiry. Univ. London. Galton Eugenics Laboratory Memoirs. 1907. III.

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Davis: An afternoon view of college life. Stanford Alumnus, 1912, 13:231.

E.g., Cases as extreme as the following can scarcely be ignored: Everyone knows how formal and how unrelated to occidental affairs is the discipline Chinese officials have undergone, yet "it is not on record in Washington that the other foreign legations are in the habit of making allowance for any lack of acumen on the part of the Chinese legation; on the contrary, the Chinese legation is regarded as one of the ablest accredited to this country." F. Angell, in a Commencement Address at Castellejo School, Palo Alto, California, 1911.

[6] Lowell: College studies and the professional schools. Harvard Graduate Mag., 1910, 19:205.

[7] Pritchett: *Ibid.* p. 65.

[8] Catherine Aiken: Methods of mind training. Am. Bk. 1895.

Harper's Mag. Editorial by Charles Dudley Warner. March, 1895.

Winch: Accuracy in school children. Does improvement in numerical accuracy transfer [to accuracy in arithmetical reasoning]? Jr. Ed. Psych., 1910, 1:557.

Education have been found to contribute something toward an understanding of the 'general' nature of voluntary control in its various phases.[9]

It rests, however, with experimental psychology to determine precisely the kind and extent of relationship that exists between the various mental processes, and this task appears to be well begun. There are already at hand some results pertinent to the question to be found scattered throughout the literature; and as a result of direct experimental investigation, the extent and causes of positive and negative influences upon one set of mental processes by reason of training upon another are, within the limits of the respective investigations, revealed. To these results we shall now turn, in the next chapter, before detailing our own experimentation in this laboratory.

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Starch: Transfer of training in Arithmetical operations. Jr. Ed. Psych., 1911, 2:306.

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Bagley: Educative process. 1907, Ch. XIII, p. 208.

Ruediger: Indirect improvement of mental function through ideals. Ed. Rev., 1908, 36:364.

[9] Scripture, Smith, and Brown: On the education of muscular control and power. Yale Psych. Studies, 1894, 2:115.

Scripture: Recent investigations at the Yale Laboratory. Psych. Rev., 1898, 6:246.

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Davis: Researches in Cross-education. Yale Psych. Studies, 1898, 6:6; 1900, 8:64.

Woodworth: Accuracy of voluntary movement. Psych. Rev. Mon., No. 13, 1899.

Dresslar: Some influences which affect rapidity of voluntary movements. Am. Jr. Psych., 1892, 4:514.

Raif: Ueber Fingerfertigkeit beim Clavierspiel. Zeits. f. Psychol., 1900, 24:352-5.

II. Evidence From the Literature of Relationship Between Mental Processes

The results of experimentation in the psychological laboratory that have come before the writer's notice and that have a direct bearing upon the question of the kind and extent of relationship between mental processes, are portrayed here in topical fashion, which takes them out of their chronological order, with the hope that the grouping of evidence about the various types of mental activity will prove more satisfactory to the reader. The year of the published results can be seen in the foot-note references.

1. *Habituation to Distraction*

Vogt[10] found that reacting on every stroke of a mentronome decreased the amount of continuous adding 47.7%; that seven days' practice reduced this to 14%; that the effect of distraction upon adding caused by synchronously reciting series of letters was decreased by practicing adding alone; that the adaptation to the distraction of reciting series of letters while adding reduced the distraction of reacting to the stroke of the metronome while learning series of numbers by heart. Among his conclusions are: (1) An adaptation (Gewöhnung) carries over from one special process to another; (2) Becoming habituated to a distraction while exercising one function, habituates to that distraction while exercising other functions.

2. *Sensitivity*

Urbantschitsch[11] sought to determine whether there is a cross-effect (Wechselwirkung) between the senses. "While a uniform excitation was present to one sense a sensation was occasioned through another, from which I perceived accurately during the functioning of the new sense if there were any changes in the sensation of the originally stimulated sense." Listening to a tone lowered the limen for light; it also affected olfactory, gustatory,

[10] Vogt: Ueber Ablenkbarkeit und Gewöhnungsfähigkeit. Psy. Arbeit., 1899-1900, 3:62.

[11] Urbantschitsch: Uber den Einfluss einer Sinneserregung auf die übrigen Sinnesempfindungen. Archiv f. d. ges. Physiologie, 42:154.

tactual, and thermal sensations. "The influence of one sense-excitation upon the sensations from other senses appears clearly to be a valid physiological law."

Epstein[12] set himself to either controvert or support Urbantschitsch's results by more carefully controlling the conditions of the experiment. He sought to find the influence of a sound-sensation upon (a) acuteness of vision, (b) acuteness of color-perception. The observer sat in a dark room and placed his eye to a telescope; the cap was removed and he reported the number of concentric rings on a rotating disc; the second stimulus was given during this fixation and he reported changes in the field of vision occasioned by it. 164 Experiments were made. Upon 60% of the reagents the sound impression increased both acuteness of vision and acuteness of color-perception; upon the other 40% it increased only the former.

Dunlap and Wells[13] gave simultaneously visual and auditory stimuli to four reagents in reaction-time experiments, and found that when the auditory stimulus was reacted to, the reaction time was about 10 sigma longer than to the auditory stimulus alone; if the visual stimulus was reacted to, the reaction-time was about 20 sigma longer than to the auditory alone, but 40 sigma shorter than to the visual alone.

3. *Discrimination*

"Volkmann[14] found that by practice of the left arm in discrimination until an initial ability of 23.6 improved to 11.2, the right arm without any practice showed an improvement from 26.4 to 15.7. Similar results were found for other cases of cross-education and for the spread of improvement in discrimination of touch at certain spots on the skin to neighboring spots."

Bennett[15] trained 16 children (average age 11 years) of the

[12] Epstein: Ueber Modification der Gesichtswahrnemung unter dem Einflusse von gleichseitigen Toneindrücken. Zeits. f. Biol., 1896, 33:28.

[13] Dunlap and Wells: Some experiments with reactions to visual and auditory stimili. Psych. Rev., 1910, 17:319.

[14] Volkmann: Ueber den Einfluss der Uebung auf das Erkennen räumlichen Distanzen. Ber. der Kgl.-Sachs. ges. d. Wiss. (Math. Phys. Col.) 1858, 10:38. Quoted by Thorndike: Educational Psych. (First Ed.) P. 86.

[15] Bennett: Formal Discipline. Teachers College, 1907, (pp. 59ff).

Speyer school in New York City, twice a week from October to March on discrimination of shades of blue, using a Milton-Bradley color-wheel. Judgments were made on whether the inner disc or the outer ring was the deeper blue (greater saturation). The stimuli were thus presented simultaneously. Tests were taken, before and after this training, on discrimination of shades formed by mixtures of (1) red+white, (2) yellow+green, (3) orange+black, and of (4) pitch. For the latter test a Gilbert tone-tester was used, F sharp being taken for the norm. Efficiency was calculated in degrees of change of the sectors, or points of tone-change, corresponding to the range of the judgment "same." The average effect of training was a reduction of this range: Boys 2.7° to 0.8°; girls 4.5° to 0.7°; or boys 65%, girls 80%. The range was reduced in the four tests:

	1	2	3	4
Boys	79%	60%	65%	28%
Girls	84%	57%	56%	23%

Since the First and Final tests were separated by five months, the practice effect of the first test could not have been considerable. Clear transfer is thus shown from improvement in discrimination of shades of blue to shades of other colors, and in a less degree to discrimination of pitch.

4. *Association*

Thorndike and Woodworth[16] trained reagents in estimating areas, weights, and lengths:

Six reagents were trained in estimating areas of rectangles from 10-100 sq. cm. in size, "until a very marked improvement was made." Tests were taken before and after this training on estimating areas of:

a. Same shape and same size
b. " " but 140-200 sq. cm. in size
c. " " " 200-300 " " "
d. Different shape and same size
e. " " " 100-140 sq. cm. in size
f. " " " 140-200 " " "
g. " " " 200-240 " " "
h. " " " 240-over " " "

[16] Thorndike and Woodworth: The influence of improvement in one mental function upon the efficiency of other mental functions. Psych. Rev., 1901, 8:247ff, 384ff.

Efficiency was calculated in amount of average error, and the final results were given in per cent showing the proportion of late to early error. In the whole table of 44 final figures 13 show lack of improvement. And of the 14 totals of the two tables, only one shows lack of improvement. The average results of four reagents (from Table IV, p. 384) show that training reduced error to 48.4% of the initial amount; that improvement was transferred to estimating the other sizes and forms to the following per cents of their original error: a. 39, b. 67, c. 102, d. 62, e. 50, f. 78, g. 86, h. 77; averages for two other reagents, who omitted c. and d., were a. 66, b. 61, e. 61, f. 84, g. 84, h. 76. Counting the complements of these per cents of error as per cent of gain, the gain in the training was 51.6%, the average gain in the tests within the field, same form, was 61%; different form, 38%; above the field, same form, 16%; different form, 51%; for all the tested abilities it was 29%. The extent to which the special practice shows general effect is, therefore, 55%.

Two reagents were trained on a set of seventeen weights ranging from 40-120 grams inclusive, 5-gram intervals, and similar except in weight. Tests were taken before and after training, on estimating (a) 8 common objects averaging 95.8 grams, the weights of which fell within the field of 40-120 grams; (b) 12 common objects averaging 736 grams, the weights of which fell above the field of 40-120 grams. Efficiency was calculated in deviations in grams. W. made in the last test in the training series 51% of the error made in the first test, T. 59.3%. W. showed in the after-training test on objects within the field over 100% of the improvement made in the training series; T. 32%; W. on the objects above the field gained 67%; T. showed no improvement. Averaging the gains of both training and test series, 44.8% improvement was made in the former and 27% in the latter. As a result of the whole experiment the special practice showed general effect to the extent of 60%.

The failure of transfer of improvement to diminish as the material estimated becomes less like the training material should be noted, for its bearing on the proposed explanation for transference through 'identical elements.'

5. *Reaction*

Angell and Moore[17] carried out a long series of experiments with three reagents in reaction-time, in which the responses were made with the hand, the foot, or the lips, to auditory and visual stimuli, in both 'sensorial' and 'motor' forms. Most of the visual series were not begun until after the auditory series (of from 700 to 1500 reactions) had been completed, and they showed a much shorter time than is usual for reaction to visual stimuli; the authors observed that the form of reaction was the same in both groups and that the decrease in time in the latter must be referred to the practice-effect of the former.

Gilbert and Fracker[18] tested three reagents on time of simple reaction, and time of reaction with discrimination, to sound stimuli, light, electrical, and tactual, stimuli; then trained two of them on reaction with discrimination, and one on simple reaction, to sound, for 12 days. Of the 27 records in the re-test with the other stimuli, 25 showed transference of improvement to both simple reaction and reaction with discrimination.

Thorndike and Woodworth[19] trained five reagents in reacting to words, in reading matter, containing both the letters *e* and *s*, by marking out the words. Before and after the training, tests were made in marking out (1) words containing, *i-t, s-p, c-a, e-r,* on similar pages; (2) *a-n, l-o, e-r,* on pages differing from the training material in length of line, size of type, and style of matter; (3) misspelled words and (4) the letter *A* from prepared sheets. Average gain in the training was 38%. In the tests the average per cent of gain was for (1) 21, 22, 10, 14; for (2) 28, 33, 31; for (3) 16; for (4) 10. The transfer of practice-effect was larger for (2) (dissimilar material) than for (1) (similar material). Altogether, the special training showed general effect to the extent of 44%.

[17] Angell and Moore: Reaction time; a study in attention and habit. Psych. Rev., 1896, 3:245.

[18] Gilbert and Fracker: Effect of practice in reaction and discrimination for sound upon the time of reaction and discrimination for other forms of stimuli. Univ. Iowa Studies in Psych., 1897, 1:62.

[19] *Op. cit.*

Carrie W. Liddle[20] sought to determine whether practice in discrimination and sorting of one set of cards bearing colors or geometric signs would assist in discriminating and sorting another set with different colors or signs. Each set of 102 cards contained six colors, or six designs, was shuffled so that no color or device repeated itself, and was sorted into six compartments. The first six cards of the pack determined the order of colors in the compartments according to which the rest of the pack was to be sorted. Nine reagents took part and the experiment continued two semesters. There was transference of practice-effect from one set of colors to the other set of colors, and to the geometric forms; and from one set of geometric forms to the other and to the colors. Increased powers of discrimination and attention were thought to be the causes of transference.

(a) Interference

Some contributions to transference of practice effect point out the fact that the effect is not always positive. It nevertheless indicates functional relationship of processes and is therefore important. Most of the material used in these contributions consists of discriminative reactions, which justifies general treatment in this place.

Jastrow and Cairnes[21] found that when two mental processes, as (1) finger-movements involving rhythm and counting, and (2) adding or reading, are carried on at the same time, the following effects are produced: (a) Simple movements are not interfered with; (b) maximum beating or beating in groups is interfered with: (c) beating in two's and three's (alternately) seriously interferes with reading aloud: (d) the maximum rate of beating hurries the mental process.

Bergström has reported experiments showing interference clearly:

[20] Liddle: Unpublished thesis for the degree of M.L. at the University of California. May, 1904.

[21] Jastrow and Cairnes: Interference of mental processes. Am. Jr. Psych., 1891-2, 4:219.

First.[22] (1) A pack of 80 cards, 10 kinds in each pack, was distributed upon 10 piles. Another pack bearing the same abstract words at the top was distributed immediately after upon re-arranged places; the results of the six reagents showed interference in longer time for the second pack. (2) Cards with pictures of common objects sketched upon them were sorted as before; but with the difference that the time between the packs was varied from 3 to 960 seconds. Series were taken by four reagents for 20 days. Interference was shown for the following intervals (in seconds) between packs: 3, 15, 30, 120, 480; it decreased regularly with the increase of the interval; two-thirds dropped away in the first minute. Time of sorting decreased greatly with daily practice but the amount of the interference did not. In the shorter intervals the reagent was acutely conscious of it; in the longer, not at all. If the interval between the packs is increased to 24 hours, the second pack is sorted in less time; practice effect has overcome interference.

Second.[23] Münsterberg's "Gedächtnisstudien" (Beihefte, Heft 4) suggested the question, "Can a given association function automatically while some effect of a previous and different association with the sense stimulus remains?" Packs of 80 cards, as before, were sorted on ten piles; orders of piles were changed and cards were changed. The answer to the question is affirmative: under certain "simple conditions, interference effect of an association bears a constant relation to the practice effect and is equivalent to it."

Bair[24] performed two experiments in which the practice effect much outweighed interference: (1) "Six keys of a typewriter are labeled with six symbols (letters or figures). Fifty-five of these letters or figures, in chance order, are now shown one by one, and the subject on seeing one taps the corresponding key.

[22] Bergström: Experiments upon physiological memory by means of the interference of associations. Am. Jr. Psych., 1892-3, 5:256.

[23] Bergström: Relation of the interference to the practice effect of an association. Am. Jr. Psych., 1894, 6:433.

[24] Bair: The Practice curve; A study in the formation of habits. Psych. Rev. Mon. Supp., 1902, No. 19.

The time taken to tap out the series is recorded. Six different symbols are then used with a new series composed of them, and the subject's time record is taken as before. This is continued until twenty different sets of symbols have been used. Although the symbols have been changed each time, there is a steady improvement, ranging for the four subjects in the following decrease in time: 62 to 52, 95 to 85, 71.5 to 58, 65 to 56. The major part of this gain could not have been due to merely getting used to the machine or to the general features of the experiments, for the fourth subject was already used to these and still gained about nine-tenths as much as the other three.[25]

"(2) The other experiment consisted in taking daily records, for twenty days, by means of a stop-watch, of the time required

[25] The relation between interference and practice has also been just recently shown by Dr. Warner Brown (Habit interference in card-sorting. Univ. Calif. Pub. in Psychol., 1914, 1:269-321). Fifty-two playing-cards were sorted, according to suit, into a row of four boxes. In the First Series, 26 reagents worked 13 days, sorting 8 packs per day (except on the 3d, 5th, and 7th days when 4 packs were sorted), during the first 8 days with the "original" order of lebels (*D C H S*), during the 9th to the 12th days, inclusive, with a new order each day for the 3d to the 6th packs and the original order for the first and last two packs. Interference in passing from the original order to one of the new orders ranged from 1% to 23%, averaging about 12% (*op. cit.*, p. 294). But in spite of the intrusion of practice in antagonistic reactions, practice on the original order resulted in considerable improvement: The actual amount of improvement from the 8th to the 13th days was considerably greater than from the 4th to the 8th days. The constant interference with practice did not prevent the steady improvement of skill with the original order (p. 307). In the Second Series, 18 students practiced card-sorting (twice a week) for 8 days, according to the same procedure as above except that 24 hours later they took an equal practice on the order *C S D H*. It was ascertained, after the elimination from the two series of all but 14 pairs of scores showing equal initial ability, (1) That antagonistic tendencies were carried over from one order to the other resulting in loss of speed at the beginning of each day's work, (2) that the interference phenomenon was confined to the first few trials of the day's sorting, (3) that it did "not affect the increase of skill in performing the action in the accustomed manner" (313), and (4) that practice on the second order helped in the learning of the first order. From the data of the First Series the author observed that "Four trials of any new order suffice to acquire a speed that it required six days, or 40 trials, to acquire in the original practice (307).

to repeat the alphabet from memory. Each day's experiment was as follows: First, the alphabet was repeated as rapidly as possible forward; second, the letter *n* was interpolated between each of the letters; third, the alphabet was repeated as rapidly as possible backward; and last, the alphabet was repeated backward interpolating *n* between each two of the letters. At the end of twenty practices in each order the subject repeated the alphabet first forward interpolating instead of *n* the letter *x* and repeating three times; secondly, interpolating *r* and repeating three times; then lastly, repeating backward and in like manner interpolating *x* and *r* and repeating three times. There was improvement in the test series, the effect of the twenty days' training with the training series being to put the abilities in the test series as far ahead as three days of the direct training would have done."[26]

He concludes, concerning the first experiment, that "continued practice in one order increases proportionately the ability to make quickly and accurately a new and antagonistic order."[27] And that "any bit of special training helps us to find ourselves. It gives us a method of orientation which leaves us in our reactions not entirely at the mercy of chance even in unfamiliar situations. The experience which we get from special training gives us a general power to meet any entirely new situation with a more favorable response than had we not had this special training.[28]

Louise E. Ordahl,[29] as a result of her work under Sanford's direction at Clark, concludes: "What Bair says in regard to the general ability given by special training, e.g., 'to a new situation we react by a general discriminative reaction and are more likely to hit on a favorable response than without this special training,' is true of all learning. For no matter what new acquisition is undertaken if it is possible to master it, some previous general

[26] Quoted from Thorndike: Educational Psychology (1st Ed.), p. 92.

[27] Psych. Rev., 1903, 10:580.

[28] Bair: Contributions to Phil. Psych. and Ed., Columbia University, 1902, Vol. IX.

[29] Ordahl: Consciousness in relation to learning. Am. Jr. Psych., 1911, 22:158.

training has either been developed by the individual or through the inherited co-ordinations of his ancestors."

McMein and Washburn[30] performed experiments with card-sorting to determine "Whether two relatively complex habits interfered with each other in a less or greater degree than two relatively simple habits." The more complex processes showed less interference.

The relation between interference and practice effect then depends upon the time between practices and the complexity of the processes. The work of Liddle and Blair seems to indicate that improvement can be made in overcoming interference by frequent changes of the associations. This would be a very important general effect of practice.

6. *Memory*

Some of the first work to show transference of practice effect in memorizing was done by Bergström[31] in connection with his investigation of interference in mental activity. He found that upon memorizing four series of non-sense syllables in succession, with but 10 seconds between series, interference was progressive; *i.e.,* each successive series took a longer time to memorize. Similar progressive interference occurred in learning 3 series of 30 digits in succession. This result conforms with that of Ebbinghaus.[32] To determine whether interference under these conditions was caused by recurring materials in re-arrangement, another experiment was performed in which the first series of non-sense syllables were made up of the letters of the first half of the alphabet, and the first series of numbers of the first half of the digits, while the second series were made up of the remaining elements. Since no materials recurred in re-arrangement and the time of the second series was greatly reduced, interference did not take place. Interference was considered an "after-image" of

[30] McMein and Washburn; Effect of mental type on the interference of motor habits. Am. Jr. Psych., 1909, 20:282.

[31] Bergström: Influence of interference upon mental activity. Am. Jr Psych., 1894, 6:267 ff.

[32] Ebbinghaus: Ueber das Gedächtniss, 1885, S. 95.

central activity, and since it occurs with associations formed from impressions from disparate senses, it opposes the dismemberment of memory for facts into different sensory types, where by this distinction it is meant that the same thing can be learned more easily by one sense than by another. The principal fact to note here is that the practice effect of the first series on the second was marked.

Bennett[33] reports transference of improvement in an experiment on memory. Two reagents took part; K. trained 28 consecutive days, learning 16 lines a day of "In Memoriam"; B. trained 35 consecutive days, learning two stanzas of "Faerie Queene" daily. K. was tested on learning a row of 30 digits each day for five days, before and after the training; B. was tested on learning a list of 15 names of places each day for five days, before and after training. K. gained in tests 58% in the reduction of time; B., *22%*.

Perhaps the most important investigation of the general effect of special training in memorizing, because of both the length and the rigor of the training, is that of Ebert and Meumann.[34] Although no control experiment was carried along, to determine the effect of the tests upon themselves in the repeated 'cross-sections,' and the quantitative results, therefore, cannot be accepted as conclusive, the amounts of gain shown in the repeated tests appear sufficiently great to create a presumption in favor of the authors' conclusions which seem more fully warranted by the qualitative part of their study.

This research continued from November, 1902, to August, 1903. Six reagents were trained on memorizing non-sense syllables, three taking 64 series, and three 48 series, of 12 syllables each. Usually the work of one day's training consisted in learning two new series and relearning two series that had been learned the preceding day. The number of the days of training for three reagents would thus be 32, and for the other three 24.

[33] Bennett: *op. cit.* (pp. 45 f).

[34] Ebert and Meumann: Ueber einige Grundfragen der Psychologie der Uebungsphänomene in Bereiche des Gedächtnisses. Archiv f. d. ges. Psych. 1904, 4:1.

Before the training, after the six reagents had learned 32 series, after the training, and after a three-month interval of no practice, tests were given. There were thus four 'cross-sections' of memory capacities taken: One for the purpose of determining initial efficiency, two for the purpose of testing the influence upon those capacities of the training on the non-sense syllables, and a final test given after a long interval without practice, to determine the durability of that influence. The tests involved (a) 'immediate memory' or the capacity of reproducing as much as possible of a series of stimuli after a single presentation; and (b) 'complete learning' or the capacity of reproducing a series perfectly after the fewest possible number of presentations. Retention was also tested by relearning after 24 hours the series that had been 'completely learned.' The series for testing both sorts of memorizing consisted of both sense and non-sense material, and were presented auditorially for the tests on 'immediate memory' and visually, by means of a revolving drum, for the tests on 'complete learning.'

The tests and results of the first three cross-sections follow:

Table I. Effect of training on 'immediate memory.'

(a) Number of units correctly reproduced after one presentation.

	Cross-sections			Per cent gain		
	1	2	3	2 over 1	3 over 2	3 over 1
Numbers	7	8.8	11.2	29	26	59
Letters	7.2	9.5	11.3	36	19	58
Non-sense syllables	5.2	6.2	7.3	20	19	42
*Italian words	5	5.5	6.5	10	18	30
*Lines of poetry	15	17	19	13	12	27
*Lines of prose	17	19	22	12	16	29

* Only two reagents.

(b) Number of units reproduced of which a third were errors.

Numbers	10.3	15.8	17.7	56	12	71
Letters	11.2	14.3	16	28	12	43
Non-sense syllables	7.7	11.2	12.2	49	9	59
*Italian words	7.5	11.5	12.5	53	9	67

* Only 2 reagents.

Table II. Effect of training, on (a) 'Complete Learning,' and (b) Retention for 24 hours. Number of Presentations per unit,—per line for poetry and prose.

		Cross-sections			Per cent gain		
		1	2	3	2 over 1	3 over 2	3 over 1
Non-sense syllables	(a)	2.11	.83	.48	61	43	77
	(b)	.49	.27	.20	45	35	59
Optical symbols	(a)	3.83	2.23	.90	42	60	77
	(b)	.68	.35	.30	49	14	56
Italian words	(a)	.273	.175	.108	36	38	60
	(b)	.056	.040	.036	29	10	36
Lines of poetry	(a)	.75	.60	.47	20	22	37
	(b)	.14	.08	.07	43	13	50
Lines of prose	(a)	1.45	.82	.50	43	39	66
	(b)	.30	.10	.09	67	10	70

From the above tables we observe (1) that the total improvement in the untrained 'special memories' compares very favorably with, indeed sometimes exceeds, the improvement in memory for non-sense syllables; (2) that the gain of the 3d over the 2d cross-section compares favorably both with the gains of the 2d over the 1st, and with the improvement made in the second period of training; (3) that the first observation above is applicable to "retention after 24 hours," but that the second is less so; the improvement in retention was not so great for the second period of training (35% as against 45%), and segregation of the scores shows that the group of reagents who took but 16 series in this part of the training is more responsible for the lack of great improvement than is the group who took 32, to the extent of the ratio 19:38 (%'s), and is more responsible for the lack of great improvement in the other tests to the extent of the ratio 8:11. It may be remarked, however, that this group had training equal in extent to that of the other group before the 2d cross-section, and yet in the test on the training material it showed less improvement in retention to the extent of the ratio 28:53 although it showed equal average improvement in retention in the other tests (48%). And it may also be noted that this group made less improvement on Non-sense Syllables in the 2d c-s, and

more than the other group in the 3d c-s, while it equalled the other in average per cent gain on the other tests of both 2d and 3d cross-sections. (4) In connection with the preceding observation it may be noted that although great improvement was shown in the wider capacity of 'immediate memory' (permitting 33% errors—see Table I.b), the second part of the training did not contribute much toward it. (5) Amount of improvement does not seem to depend upon similarity of the test to the training material; *e.g.,* Numbers in Table I. and Optical Symbols in Table II. were more dissimilar to the training material than any of the other non-sense tests, yet improvement in the former exceeds and in the latter equals that shown on the training material; and the gain shown on lines of Prose, in Table II., which differs greatly from the training material in the form of connection between the units of the series, is higher than that shown on lines of Poetry which in the respect noted is more similar to the training material.

The permanence of the improvement in memorizing, as shown by the fourth cross-section,[85] would seem to support the claim that it was not effected by the test practice.

Unless we assume that all the gain on the tests, other than on non-sense syllables, is the result of the practice effect of the preceding tests, we must refer some of the gain in these tests to the training on non-sense syllables; how much, cannot be safely estimated until the tests are repeated, without training, under the same conditions.[86]

[85] Five of the reagents were here given tests on non-sense syllables, and two of them on verses of Poetry, after an interval without practice. This interval was 75, 85, 91, 146, 156, days respectively. There was no decrease in efficiency; some of the reagents showed an increase.

[86] This appears to have been done by Dearborn (Psychol. Bull., 1909, 6:44) whose results "indicate that a considerable part of the improvement found must be attributed to direct practice in the test series, and not to any 'spread' of improvement from the practice series proper." G. E. Müller (Zeits. f. Psychol., 1905, 39:111-125), Wessely (Neue Jahrb. f. Päd., 1905, 8:379-380), Sleight (Br. Jr. Psychol., 1911, 4:390ff), among others, have also criticised the quantitative evidence in the original research. A pupil of Meumann's, however, who took the precaution of performing control experiments, presents, in a Dissertation published from Zürich, evidence that special training

The introspective evidence, as noted above, seems more conclusive than the quantitative. The training effected (1) a change in the whole psychical habit of memorizing, which was applicable to the varied test material: Distaste for the exacting work changed to zest; muscular tensions decreased in intensity and extent; innervation for the work became strong and constant; attention became more economically directed over the parts of the presented material; concentration became more constant; etc. And it effected (2) a change in the method of memorizing: The progress in 'complete learning' became methodical, and learning a series which soon after the beginning of the training was carried on in the various successive stages by definite and distinct motives, as (a) orientating, (b) apperceiving, (c) combining units into a rhythm, (d) anticipating syllables, (e) proving memory, became more of a continuous process in which the various motives were economically combined; the mnenonic aids at first grasped at by all reagents were advantageously discarded, etc. The experience of the reagents thus attests the fact of the general effect of their special practice, and reveals in some manner the cause of this general effect.

Fracker[37] makes another important contribution proving general effect of training when the materials memorized are of a simple nature. A group of four untrained reagents took the tests with the trained reagents, permitting determination of practice effect of the first test upon the second, and the plan and control of the experimentation are excellent.

Eight reagents were given four weeks' training (two or three days a week) in memorizing series of 9 sounds made up of four intensities. These were produced by an electro-magnetic fork and were delivered through a telephone. The four different intensities were produced by switching into the circuit different resistances. Improvement was made by all but one reagent (Fs.).

in memory is also general training in memory. (Radossawljewitsch: Das Fortschreiten des Vergessens mit der Zeit, 1907, S. 182).

[37] Fracker: On the transfer of training in memory. Psych. Rev. Mon. Sup., 1908, No. 38:56-102.

Before and after the training the eight trained and the four untrained reagents took the following memory tests:

1. Poetry (Two stanzas of "Eve of St. Agnes")
2. Order of Four Grays (40 groups)
3. " " Nine Tones (20 groups)
4. " " Nine Grays (20 groups)
5. " " Four Pitches (40 groups)
6. " " Nine Geometrical Figures (5 Trials)
7. " " Nine Numbers (10 series of 9 double numbers)
8. Extent of arm-movement (10 trials for each of 3 standards)

No's 2, 3, 4, 5, were given in "double fatigue order" to equalize fatigue and practice effects upon them.

The relation of the tests to the training series was as follows:

No. 2 different in content, same in method.
No. 3 same in content, different in method.
All others, different in both content and method.

No. 2. A group consisted of 4 grays (No's 2, 7, 30, 45,—Hering) exposed at the rate of one second, remaining exposed one-half a second, with an interval of 4 seconds between the groups. In this interval the reagent responded aloud in numbers 1 to 4, 4 being the darkest gray, reproducing the order of the 2d preceding group.

No. 3. A group consisted of 9 intensities of sound, delivered at the rate of one second, each continuing one-half second. In a nine-second interval between groups the reagent responded aloud in numbers 1 to 4, 4 being the loudest sound, reproducing the order of the preceding series.

No. 4. Same as No. 2, except that 9 grays were given in a group. The reagent responded aloud in numbers, during a nine-second interval between groups, as in No. 3.

No. 5. Same as No. 2 in method, except as to the response, which was made by naming Do, Mi, Sol, Do-2. The stimuli were the notes of the major chord struck upon a piano.

No. 6. The geometric figures were drawn by joining three straight lines (two long, one half-length) so that they joined only at the ends or in the middle, the long lines always adjoined, and formed right angles, none crossing. The nine symbols were

exposed simultaneously for 10 seconds. The reagent responded by drawing the figures, within a time limit of one minute.

No. 7. Nine two-place numbers were read aloud at the rate of one and one-half seconds. The reagent responded by recording within the time limit of 15 seconds.

No. 8. The reagent, with eyes closed, moved his finger with free arm movement along a glass rod from a stationary piece of tubing to one adjusted by the experimenter; he moved his finger out and back twice; then moved it out to the position he estimated to be the same (the adjustable tube being removed); three standards were used.

The tables show that of the 8 trained reagents six made their greatest gains, and the others made large gains, in No. 2, where the material was grays, and the method was the same as in the training on sound; the other two made their greatest gains, and three others made good gains, in No. 3, in which the content was the same as in the training, but the method was different. In No. 4, four made large gains. In No. 5, in which the method was the same as in No. 2, but in which the material was series of pitches, responded to by name, four made large gains. Of the tests which differed widest from the training in material and method, three made large gains in No. 6 (Geometrical figures); three made fair gains in No. 7 (Nine numbers), and one in No. 8 (Movement). In No. 1 (Poetry) four made fair gains.

By grouping the tests in the order of similarity to dissimilarity as compared with the training, and averaging the per cent gain[88] of the trained and of the untrained reagents, we get:

	Similar				Dissimilar			
Tests	2	3	4	5	6	7	8	1
Trained reagents	36%	22	19	10	13%	4	0	7
Untrained reagents	4	11	10	-2	8	0	-1	2
Difference	32	11	9	12	5	4	-1	5

The average gain in training was 21%.

[88] The per cents gain are the differences between the scores which were expressed in per cent of a perfect score; they are not reckoned upon initial efficiency.

And if we average the per cent gain for the respective reagents, we may compare the (a) test gains with the (b) training gains, and the (a) gains of the trained with the (c) gains of the untrained reagents:

Reagents		1	2	3	4	5	6	7	8	9	10	11	12
	(b)	32	25	-9	41	27	29	17	(9)				
	(a)	10	15	6	15	30	15	6	14	(c)5	8	10	13

The average gain for the trained reagents on the similar tests was 22%, on the dissimilar 6%; for the untrained reagents 6% and 3%. Which indicates that gain in the dissimilar tests was harder to make; that there was greater transfer of improvement in the training to the similar material than to the dissimilar material, and that there was transfer to the dissimilar. The greatest transference to the similar material, however, appears to have been made on No. 2, in which the method and not the content was similar to the training.

But Fracker's emphasis is rightly placed on introspective analysis rather than on quantitative results, and he gives us a good account of the processes involved in the work of his reagents.

The training in memorizing the order of four intensities of sound developed for nearly all the reagents individual systems of visual, visual-auditory, or visual-motor, imagery, involving four steps or four positions by which the sequence of presented intensities was remembered as imaged movement among these positions. These systems of imagery were carried over to the tests involving sequence of four graded units (No's 2, 3, 4, 5) and replaced, for the trained reagents, the changeable and tentative methods employed by all reagents, in the first series of tests. Where the tests were more favorable to the application of this developed imagery, as with the four grays (No. 2), it contributed most effectively to the increase in the score; where conditions did not permit its application *in toto*, as with series of nine units before response (No's 3, 4) and with a series demanding a different form of response (No. 5), there was interference and its efficiency was decreased. Apparently, the dependence upon the system of imagery where interference is great, as in the changed form of

response (No. 5), results in lower scores than were made where the imagery was seen not to apply and reliance was placed upon other and more general effects of practice: more improvement was shown with the simultaneously presented geometric symbols (No. 6) than was made with the pitches (No. 5). Those other effects of training responsible for improvement here, and also in the tests on numbers (No. 7) and poetry (No. 1) appear from the introspection of the reagents to have been (a) systematic grouping of material, (b) freer use of imagery in connection with this grouping, (c) more economic distribution of attention, (d) better concentration of attention, (e) more confidence in power to master the situation, etc. Fracker explicitly states three factors of improvement in training and of transference to the tests, besides the development of these systems of imagery: (a) attention to the essentials, (b) association responsible for building the systems of imagery, (c) automatic use of the imagery where applicable.

It is the chief virtue of this research that it has made clear the importance of individual systems of imagery as factors in the general effect of special practice in memorizing. So far, representative imagery had not been given, in researches connected with the theory of formal discipline, the attention it merits, although its place in mental life is well known.[89]

The ancients, according to Cicero, based their systems of memory training upon spatial position or location, and it is not unusual today for university students to fix points in a lecture in mind by ranging them along the windows and doors of the room.

The psychological laboratory has revealed the prominence of this kind of imagery in the mental organization of not a few re-

[89] The writer desires in this connection to allay the misapprehension on the part of the author (*op. cit.* 98ff.) that his results do not accord with those published by Coover and Angell (Am. Jr. Psych., 1907, 18:327) with respect to the relation between imagery and improvement in practice and between imagery and transference of practice-effect. Representative imagery may be of high value in processes of memory and at the same time be one of the chief distractions in processes of discrimination and of reaction with discrimination and choice.

agents. As an example, Miss Gamble[40] uses systems of representative imagery extensively in memorizing series of stimuli, whether they are odors, colors, or non-sense syllables. The increase in facility in memorizing smells was due to a newly acquired system of associating members of a series with spots on the table-top, which she had previously developed while working with colors. She has worked in smell experiments for eleven years and learns large series of smells with phenomenal facility, yet she has no true smell imagery; her olfactory impressions are replaced primarily by color-images suggested by the materials. With respect to the influence of practice on associations, she says that representative associations remain but that auxiliary associations (as, black-pink, being held by "red eyes of a mourner"; or green-yellow, by "green grass a hunting dog runs over and the corn-meal mush he is fed on";) drop away.

Sleight[41] has recently made a substantial contribution to the question of transference of improvement in memory. He takes his departure from a criticism of the work of Ebert and Meumann, Fracker, and Winch. His objections to the first are (1) too few reagents for statistical treatment of results, (2) no control series to determine the practice-effect of the tests themselves, (3) no evidence that the tests in the various cross-sections were of equal difficulty, (4) inadequacy of the per cent form of statement of results, for one reason because per cents are not equivalent when they are not reckoned upon equivalent stages of practice. His objections to the second are confined to the first of the four just quoted. These criticisms will receive some attention in theoretical discussion later.

His first series of experiments were performed with children of three girls' schools, numbering 21, 28, 35, respectively (average age, 12 yrs. 8 mo.).

Ten different kinds of tests were given to ascertain the memorizing power of each child; these constitute the first 'cross-section,' upon the combined results of which the children of each

[40] Gamble: Study in memorizing various materials by the reconstruction method. Psych. Rev. Mon. Sup., 1909, No. 43:1.

[41] Sleight: Memory and Formal training. Br. Jr. Psych., 1911, 4:386.

school were arranged in order of merit and divided into four approximately equal sections of equal merit; one group was practiced on learning poetry by heart, one on tables, one on prose substance, and one had no practice but spent the time on arithmetical problems or some other task not involving memory work. The practice period lasted six weeks, four days a week, 30 minutes a day. A second cross-section of tests was taken in mid-practice, a third at the close, and a fourth after six months.

In practice (1) the poetry group repeated line by line after the experimenter until the average child could repeat the whole without help. Meter and lines varied. (2) The group on tables learned multiplication, denominations, squares, fractions, etc. (3) The substance-prose group heard read twice selections from scientific, geographical, historical, narrative material, and reproduced the substance of the narratives.

The ten tests were intended to appear to develop out of ordinary school work and were representative of many different processes regularly involved in memory work; they included verbal and logical associations, in couplets and continuous, of letters syllables, and names; spatial associations with one presentation and with several.

Averages were tabulated; and the differences between the averages of cross-sections one and two, two and three, and one and three, for each group of children for each test, were divided by the average of the test standard deviations of the three respective schools. A table of significant values was formed by subtracting the difference-score of the unpracticed group from the difference-scores of the three practiced groups, in each test for the three test-comparisons. Where these values (the difference between the difference-scores of the practiced and unpracticed children) were over three times as large as the probable errors, they were accepted as significant. Since we are limited to a consideration of the 'significant' values, of which there are a few, it is interesting to note that (1) the group trained on poetry showed transfer effect to non-sense syllables and the map test having lost in the test on poetry by an insignificant amount. (2) The group

trained on tables showed transference to points (spatial memory) and to non-sense syllables, having lost on dates by an insignificant amount. (3) The group practiced on prose-substance showed transference to prose-substance and to names. (4) Of the three trained groups only one shows transference to the test most similar in material (Prose-substance) to their training. (5) If the indications of transference are limited to those values which "present really strong evidence" (five times their probable error), but three cases remain: Prose-substance to prose-substance, poetry to non-sense syllables, and tables to non-sense syllables, in the order named, the last being the greatest. (6) The only negative transference occurred from tables to dates, in which arbitrary 'paired' associations were common, but in the latter the sequence of the pairs was disturbed.

The following causes of transference were conjectured: (1) From poetry to non-sense syllables, the common element of rhythm; (2) from tables to non-sense syllables, rhythm and arbitrary associations; from tables to points (spatial memory), visual imagery; (3) from prose-substance to prose-substance, identical material.

Since the results of this experimental series with children were of an unexpected nature and their interpretation had to rest wholly upon statistical analysis, another series was carried out in order that they might be confirmed or contradicted by the new results and introspective analysis.

The second series of experiments were conducted upon two classes of young women (average age. 18-19 years), first-year students, in the Training College (London).

The method and tests were approximately the same as in the first series, except that but six tests constituted a cross-section. The training of three groups of poetry, tables, and prose-substance respectively, continued twelve consecutive days (a Sunday excepted), 30 minutes daily, and differed from the training of the children in that poetry and tables were learned from manuscript instead of from oral repetition. The statistical treatment of the results yields six 'significant' values, and two of these are nega-

tive: (1) The group practiced on poetry showed transference to nonsense syllables and to poetry; (2) the group practiced on tables showed transference to dates; (3) the group practiced on prose-substance showed transference to prose-substance, and negative transference (interference) to non-sense syllables and consonants.

Causes for transference, based largely upon introspective analysis, were presumed to be: (1) From poetry to poetry, identical material and rhythm; from poetry to non-sense syllables, rhythm; (2) from tables to dates, visualization; (3) from prose-substance, to prose-substance, identical material; negative transference to non-sense syllables and to consonants, repugnance for mechanical learning after training on easier logical material.

This second series seems to be quite independent of the first, the significant values of the respective tables of general results agreeing in but one case. The introspections of the adults throw no light upon the results from the children, and fail, in their naïveté, to furnish satisfactory explanations for their own results; they are not to be considered comparable to the introspections of the reagents of Ebert and Meumann, and of Fracker. The results of both series must stand on statistical analysis alone.

In his analysis of results, Sleight finds Thorndike's early law of 'Identical elements' too simple. Cases of transference shown in the above paragraphs do not follow it: (a) The group practiced on tables did not show improvement, but loss, in their 3d test on dates; due to the fact that in the tests they were told the number of repetitions that would be given, whereas in the training they were not, which resulted in a change in the direction of the attention; and (b) the group trained in poetry lost in their third test on poetry, probably for the same reason. Transference to the tests more remotely related to the training material was occasionally large; the greatest transference being to tests on non-sense syllables from training on poetry, and on tables. "The relation which produced transference is not necessarily (a) an external relation perceivable by an observer, nor (b) a relation perceivable by the learner; but (c) a common factor, of which the individual mind makes use, consciously or uncon-

sciously. The individual's awareness of the usable common element may produce an earlier and greater effect." The common element "must be separable from the complexes" in which it occurs. This disintegration resists transference. "The factors which make for transference are similarities of a fundamental nature, such as specific forms of attention, imagery, rhythm; in short, similarities of procedure;"[42] changes in these affect transference more than changes in material.

The general conclusion to which the author is led is that "Specific memory training is specific in its effects."[43]

It appears to the writer that there are apparent reasons which mitigate this conclusion: (1) The unpracticed group was not unpracticed, since these tests involved processes largely exercised in the ordinary work of school. This influence tends to erase the difference between the practiced and the unpracticed groups. (2) There is sufficient indication by significant positive and negative values, of relationship of processes to count against merely specific effect of practice. (3) The assumption that "the mental processes have probably been independent" when the influence of the training is not revealed by "significant" difference-scores, is opposed to the general introspective evidence of other investigators. (4) The criticism of irregularity of results, applied to Winch by the experimenter, seems applicable here, since, as was noticed above, the two tables agree in but one entry.

Miss Gamble[44] in the course of memory investigation with odors, colors, and non-sense syllables, found a great increase in facility in memorizing smells after practice in memorizing colors with which she developed a spatial system of representative imagery. The new system was carried over. And "The results of G. seemed to show that practice gained in the earlier experiments with smells and colors was transfered to the learning of non-sense syllables."

Rall[45] tested two groups of students, upon each of three days, in memorizing poetry (Evangeline) and in memorizing non-sense syllables. One group (44) trained on memorizing for four weeks, 20 minutes a day, individuals choosing various material, such as poetry, prose in English and in foreign languages, irregular verbs and vocabularies in foreign languages. Improvement in training was measured by comparing the last three with the first three days. The second group of 28 took no training.

Results showed wide variations: Of the 44 trained reagents, 4 lost in the training and one lost in the Evangeline tests; 6 out of 34 lost on the non-sense syllables. Of the untrained group, 4 out of 28 lost on Evangeline, 3 out of 16 lost on non-sense syllables. In the training 22 improved more, 20 less, than in the Evangeline test, and 2 improved the same amount; 23 out of 34 improved more (or lost less) and 11 improved less in the training than on the non-sense syllables. The following table gives the average improvement in per cent:

	No.	Training	Evangeline	Non-sense Syllables
Trained	25	32.5	26.9	24.5
Untrained	20		17.8	12.0
Difference			9.1	12.5

In this experiment, then, 25 students gained in training 32.5%, of which 28% was transferred to the poetry test, and 38% to the test on non-sense syllables.

A second investigation was made which agreed with the first in showing the general effect of special practice, but the amount of the transference was smaller.

Radossawljewitsch[46] in conducting experimentation directed by Meumann found that special practice in memorizing improves memory in general.

[45] Rall: Some experimental evidence on the transfer of training in memory. Psych. Bull., 1912, 9:88.

[46] Radossawljewitsch: Das Behalten und Vergessen bei Kindern und Erwachsenen nach experimentellen Untersuchungen. Päd. Mon. Von Meumann. 1907.

Miss Talbot[47] in training her visual memory, not in power but in frequency of use, found general effect in its making memory more sure.

7. *Voluntary Control*

Book[48] found, in his investigation of learning typewriting, that in learning to 'short-circuit' to a higher order of habits, besides habits of manipulation, there were involved 'habits of control.' These with other mental habits "when developed in the sight method of learning, were carried over to the touch method of learning and were used to good effect."

Judd and Cowling[49] report that improvement in drawing an imaged form with the eyes open was transferred to efficiency in drawing with the eyes closed.

Wallin[50] trained two observers in nonocular control of reversions in a number of reversible perspective outlines, such as a book or a pyramid. "Practice consisted in the attempt to uniformly envisage the infrequent or non-predominant perspective." Improvement in 9246 trials, expressed in per cent of successful control, amounted to an average of 42% between the averages of the first and last 20 days (40% and 82%). Tests showed that the improvement was shared by the unpracticed eye. "The effects of practice are central; the training of the one eye established certain cortical tendencies and mental attitudes. The unused retina therefore tended to respond in harmony with the central disposition." Also, earlier in the experiment, reversions occurred about two and one-half times faster in direct vision than in peripheral vision; after practice, reversion occasionally occurred most readily when the figure was in peripheral vision; there was "transference of fixation motives attaching to the fovea to the peripheral retina. . . . The foveal tendency was transmuted into a 'generalized retinal habit.' "

[47] Talbott: Attempt to train the visual memory. Am. Jr. Psych., 1897, 8:414.

[48] Book: Psychology of Skill with special reference to its acquisition in Typewriting. Univ. Mont. Bull., 1908, 53:75.

[49] Judd and Cowling: Studies in perceptual development. Psych. Rev. Mon., 1907, No. 34:349.

[50] Wallin: Doctrine of formal discipline: Two neglected instances of transfer of training. Jr. Ed. Psych., 1910, 1:168.

8. *Summary*

The following summary gives briefly the results of the psychological investigations, coming before the notice of the writer, and reviewed in the preceding pages, which have a direct or indirect bearing upon the question of functional relationship between various mental processes:

(1) Improvement in habituation to distraction is general (Vogt); (2) sensitivity of one sense is increased when impressions from another are simultaneously received (Urbantschitsch, Epstein); (3) reaction-time to one of two simultaneous stimuli is different from the time to either alone, being shorter to a visual stimulus when a sound stimulus is also given than to a visual stimulus alone, and longer to a sound stimulus when both are given than to a sound stimulus alone (Dunlap and Wells); (4) increase in sensible discrimination of two points is shared by surrounding areas (Volkmann); (5) improvement in discrimination of shades of blue (for school children) was transferred to facility in discrimination of shades of other colors, and of pitch (Bennett); (6) improvement in estimating areas, weights, and lengths, was transferred to capacity to estimate areas, weights, and lengths, different from those used in the training (Thorndike and Woodworth); (7) time of simple reaction, and time of reaction with discrimination, to light, electrical, and tactual, stimuli, were reduced through training on simple reaction or reaction with discrimination, to sound stimuli (Gilbert and Fracker); (8) reaction time to visual stimuli was lowered by previous practice in reaction to sound stimuli (Angell and Moore); (9) improvement in marking out words containing each of two given letters, on pages similar to and different from those used in training, and in marking out capital *A's* from a sheet containing 500 capitals, resulted from training in marked out words containing the letters *e* and *s* (Thorndike and Woodworth); (10) there was transfer of practice-effect in sorting cards, from one set of colors to another set of colors, and to geometric forms, and from one set of geometric forms to another, and to the colors (Liddle); (11) functional relationship and interdependence of mental processes are shown by the phenomena of inter-

ference: (a) simultaneous processes may interfere with each other or augment one of them (Jastrow and Cairnes); (b) sorting a pack of cards in re-arranged compartments immediately after sorting another, takes longer time, and in learning rows of non-sense syllables successively, the time becomes progressively longer if they possess recurring elements (Bergström); (c) frequent changes in typewriter-reaction, however, result in capacity to make new and antagonistic series of reaction in less time, and practice in repeating the letters of the alphabet with the interpolation of a given letter between each two, increases capacity to repeat the same series with the interpolation of a different letter (Bair); (d) and there is less interference between complex than between simple processes (McMein and Washburn); (12) training in memorizing poetry improved memory for digits and for names of places (Bennett); (13) memorizing non-sense syllables improved memory for letters, numbers, words, meaningless syllables, Italian words, verses of poetry, lines of philosophic prose, and optical symbols (Ebert and Meumann); (14) memorizing series of sounds improved memory for series of grays, tones, pitches, a square of geometrical figures, and verses of poetry (Fracker); (15) training of memory (for children and students) upon matter similar to schoolwork, resulted in a few significant gains in memory for material similar to, and different from, that used in the training, and deteriorated memory for some similar material (Sleight); (16) memorizing colors gave greater facility in memorizing odors, and practice gained in memorizing odors and colors was transferred to memorizing non-sense syllables (Gamble); (17) memorizing poetry or prose in English or in a foreign language, or irregular verbs or vocabularies, improved memory for poetry and for non-sense syllables (Rall); (18) improvement in voluntary control was carried over from sight to touch typewriting (Book), from drawing with the eyes open to drawing with the eyes closed (Judd and Cowling), from use in connection with one eye to use with the other, and from the foveal to the peripheral vision (Wallin).

An examination of the data reveals the fact that special practice is not wholly general in its effects; is often not largely gen-

eral, but probably is always somewhat general. Under the conditions of the experiments it usually ranges in amount from a fourth to three-fourths of the gain shown in the training.[51]

Of greater importance than the fact of the general effect of 'specific training' however, is the theory that will account for all the facts that have come to notice through the course of investigation and that point to the relationship of all mental processes, but to a relationship that is by no means a simple one. Progress toward such a theory is made by the discussions of investigators, quoted above, who have subjected their numerical and introspective results to a more or less thorough analysis. But since there is, on the surface at least, some conflicting evidence, further work is necessary to unravel the tangled skein of positive and negative relationships, and to account for some apparently anomalous results[52] which occasionally occur.

[51] It is interesting and perhaps significant that the distinction between general and special effects of practice is so generally recognized by the Danes that their language provides separate terms for them (Faerdighed, general; Udenadlaeren, special). *vid.* Meumann: Beiträge zur Psychologie des Zeitsinns. Phil. Stud., 1893, 8:435.

[52] Of which further notice is taken on pp. 64ff.

PART II

EXPERIMENTAL

I. PRINCIPALLY QUANTITATIVE

The following four experiments (performed 1903-5) took their departure from the work of Thorndike and Woodworth.[1] The amount of transference was still in question, and the theory was still that of "identical elements" of a relatively simple nature, largely motor. Although the principal contribution is quantitative, the analysis of processes is not neglected—all experiments were accompanied by introspections.

1. Experiments on the More Complex Processes

In order that we could start on an even footing with the investigation referred to, it was necessary to repeat some of the experiments; the following two were chosen: a. Marking out words containing two given letters, and b. Estimating weights.

a. Marking Out Words

Two reagents were trained for 11 days in marking out words containing *e* and *s* in selected columns of the "Outlook" Magazine. Each reagent looked over 12,000 words in each day's practice.

Tests were taken before and after training, in marking out

(1) Words in "Outlook" columns containing *e-s, i-t, s-p, c-a, e-r*.

(2) Words on manuscript pages containing *a-n, l-o, e-r*.

(3) Common nouns in "Outlook" columns.

(4) Words in "Outlook" columns containing *e-s*.

The manuscript pages were prepared with a script 'type-wheel'

[1] *op. cit.*

on a Blickensderfer typewriter and were typed in purple ink. They differed from the printed columns in (a) length of line; (b) color, (c) size, (d) form of letters; (e) letter-spacing; (f) line spacing. This provision was made in order that we might determine if marking out words consisted simply of reactions to visual symbols. If so, then training the *e-s* function on printed matter would show much less effect upon the functions employed on the manuscript pages than on the printed columns. And if improvement in the trained function consisted to an appreciable degree in eye-movements or other habituation to the printed material, there would also be less improvement carried over to the functions employed on the manuscript pages.

The results in time and accuracy are given in Table I (Appendix A, p. 259) and also in per cents in Table II (p. 260). From Table I are drawn the two curves on Plates I and II (p. 261) which show in absolute amounts the acquired efficiency (in speed) in the *e-s* function, and the amount efficiency in the other functions was increased thereby, for the two reagents.

From Table II are drawn the curves on Plates III and IV (p. 261) which show the per cent of acquired efficiency in the trained *e-s* function and the per cent of improvement made in the tested abilities of other functions.

Plate VII (p. 262) shows the course of efficiency with *e-s* words during training.

Calculating gain by finding the complement of the per cent of time, the two reagents gained in the training series 57% and 31%, in the test series on "Outlook" columns 50% and 20%, on the manuscript pages 30% and 30%; on nouns 14% and 6%, and on all 42% and 24%. The special practice shows general effect, therefore, to the extent of 74% and 77%. That the improvement in the final tests is not due to the practice-effect of the first tests may be learned from Table I, in which are shown the results on *e-s* words with which the first test began and ended; For Gs. this effect was 12% , for Cr., –3%.

The accuracy is quite uniform for the tests, although in the training considerable improvement was made. (Table II, Plates V and VI, pp. 260, 262.)

Our results in comparison with those of Thorndike and Woodworth are given in the following table. They show about the same improvement in training, but more general practice-effect 75% instead of 49%.

Table Comparing Data
Per cent Improvement

Reagents		In Training	In Tests On Similar Data	In Tests On Dissimilar Data	Avg.	Extent of general Practice-effect in %
Thorndike and Woodworth's Reagents	Ber.	19	12.5	4	10	53
	Br.	51	21	35	19	37
	Be.	37.5	16.5	30.3	21	57
	Wh.	44	5	25	10	23
	EMT.	36	24	33	25	69
Our Reagents	Gs.	57	50	30	42	74
	Cr.	31	20	30	24	77

(The per cents are reckoned on the time of the first tests; in last column, on the amount of improvement in the training.)

The table shows more improvement in tests on the dissimilar data than on the similar data, by 4 reagents in Thorndike and Woodworth's experiment, and by one in ours.

(1) *Conclusion*

Our results seem to indicate that habituation to the training data was not a great factor in transference of the practice-effect. Some slight improvement may have been due to habituation of eye-movement and eye-adjustment to the word-hunting process, to facility in pen-manipulation and to the dropping away of gross motor accompaniments of mental effort.[2] A little may have been due to learning a method of looking for words; as, keeping more prominent in mind an image of the least frequent letter and using it as a cue. *But the transferred improvement seemed principally due to reducing the recognition of a word as containing given letters to its essential process.* Introspections note the ease and automatism of the process in the after-training tests:

[2] Lindley (Am. Jr. Psych., 7:491ff) finds a considerable list and points out that some of them are detrimental.

Cr. remarked, after test on *c-a*, "seemed almost as easy as *e-s*, though the words as recognized were not of that familiar cast which some *e-s* words had acquired." Gs. remarked, after test on *e-r*, "Seemed to me as if I were marking almost as mechanically as I had done the *e-s*." Gs. remarked, after test on *a-n* words in manuscript, "marked with great facility of recognition and very mechanically." *The process of recognizing words as containing given letters had been relieved of the unnecessary and retarding accompaniments (kinaesthetic, motor, and acoustic images)* noticed in the introspections of the first tests and in the early training.

These retarding accompaniments consisted in (a) repeating over and over again, in inner speech, the names of one or both of the letters sought, or their sounds[8]; and in (b) repeating the separate words, or actually reading the text, in order to determine whether the words contained the sounds which were held in mind as auditory images. Even when the method was adopted to recognize by visual images, these were strongly supported by kinaesthetic-auditory imagery; which indicated that the most difficult feature of the exercise lay in recognizing words as containing the critical letters.

Training reduced this process to an almost automatic visual-motor act, and greatly reduced the time of a given performance. There was no kinaesthetic or auditory tendency in the process, in the final tests, except where the process was felt to be specially difficult (Gs. could scarcely distinguish the *a's* from the *o's* in the manuscript, and consequently had a tendency to pronounce the sound of *a* at times; Cr. had some difficulty in recognizing *i-t* in the printed columns). This chief factor of improvement in the training is identical with the factor of improvement in the tests.

The processes for both reagents, in the different experiments in the first test, were various: (1) reading, (2) kinaesthetic-auditory cue of letter-names, (3) of letter-sounds, (4) visual

[8] Secor (Am. Jr. Psych., 11:236) found auditory and articulatory factors to be aids, especially with difficult material, but not necessary elements in visual reading.

image cue of letter forms, (5) imagery of the one letter only as the cue, (6) lines, or words as units for search, (7) mechanically searching for projections of letters, etc., sometimes varying within the single experiment, but usually playing the dominant role throughout an experiment.

In the final tests the process was almost uniform, for each reagent, throughout the different experiments. That this change was not merely a change in method, is indicated by the fact that it took five days of training (12,000 words per day) to get rid of the retarding accompaniments of the recognition process. (See practice curve in Plate VII, p. 262.)

Some special factors were noticed in the training which would not contribute to general effect: certain common words often recurring were reacted to by the word-marking impulse without engaging the word-inspecting process; and the familiarity of the images of the capital forms of the letters rendered capitalized words easily recognizable.

In the first test Gs., in marking out *s-p* words, took *p* for the cue and ran his eye along under the line for the projecting stem; and *l-o* words in the manuscript, above the line for the loop of the *l*. In the final tests, although *p* and *l* were the visual cues, respectively, the words were searched for the complete letters. (This accounts for the smaller gain on *s-p* and *l-o* words as shown by the tables and charts, in the Appendix A, pp. 259ff.) Cr. used the same trick with *s-p* words in the first test, but not in the final, which yielded him also a very small score—about half of the score for the *e-r* words.

The observation that marking out words containing different pairs of letters engages essentially different processes cannot be taken as a criticism of the claim that the main factor of improvement is also a factor of transference. Marking *e-s* words is not a simple but a various process, even with a single reagent. It does not only change as a result of training, but at any one sitting it varies with words of different length and of different distribution of the critical letters. These variations may be so regular as to show in a large amount of marking (by a given reagent), various constant errors. *E.g.*, Gs., in his training on *e-s* words, omit-

ted a much greater proportion of 6-letter words than any others, and of words in which *e* and *s* were separated by three or four letters than any others, of words also containing *x* than of those also containing *ch, є, ç, or z.* Cr., in his training on e-s words, omitted a much greater proportion of 4-letter words than any others; of words in which *e* and *s* were separated by four letters than any others; of words also containing *z* than also containing *ch, є, ç,* or *x.* Gs. recognized *e-s* words principally through kinaesthetic or sound image of *s, x* was his great distraction, and half the words he marked in error contained *є* interpreted as *ç.* Cr. recognized *e-s* words principally through their visual images, using *s* as a cue, and *z* was his great distraction.

Although the process varies not only with various words and with various reagents, general effect of the special practice is shown quantitatively by the tables and qualitatively by the introspections, to be the rule for both similar and dissimilar data. And we take the principal factor of improvement to be essentially general in nature.

b. Estimating Weights

Two reagents were trained for 14 days on a set of 17 Chicago suggestion blocks ranging from 40-120 grams, all similar except in weight. Each reagent took 100 series, making 1700 judgments. (See Tables V and VI for data of the first and last series, pp. 263-4.)

Tests were taken before and after training on estimating (a) Ten common objects, averaging 67.5 grams in weight, and all falling within the 40-120 gram field; and (b) Ten common objects, averaging 552.7 grams, and all falling above the 40-120 gram field. (Detailed results are given in Tables VII to X, pp. 264ff; averages, in Tables III and IV, pp. 260, 263.)

All weights were lifted from a cushioned surface through a distance (about six inches) limited by a taught cord, during a given time (one-half second) controlled by a metronome, and were replaced in the same time,

Efficiency was measured in per cent—the ratio of the amount of deviations in the final to the first tests. The following table gives the averages for each reagent:

Reagents	Training Series 40-120 g.	Test Within Field 40-120 g.	Test Above Field
Gs.	74	71.6	56.7
Cr.	80	70.8	244

If per cent of improvement is found by taking the complements of the per cent of error, we get the following comparison of averages with the results of Thorndike and Woodworth:

Reagents		Training Series 40-120 g.	Test Within Field	Test Above Field
Thorndike & Woodworth's Reagents	W.	49	62	33.2
	T.	40.7	13	-1.2
Our Reagents	Gs........	26	28.4	43.3
	Cr.	20	29.2	-244

From the tables it is noticeable that our results are more uniform for the two reagents than are those of Thorndike and Woodworth's. In each case one reagent shows no improvement in the tests on objects above the field, Cr. making 244% more deviation in his final than in his first test. With this exception our reagents showed in the test series more improvement in every case than was made in the training, and thus show more general practice-effect than was shown in the original experiment.

Cr.'s loss of 244% in the test on objects above the field is easily explained by his introspection that his estimates "were mere calculations upon the old reproduced kinaesthetic image of the 1000-gram scale weight" which was accidentally handled just before the first test was taken, and by the fact that his deviations in the first test were remarkably small, totaling only 15% of the total weight lifted; (his deviation on objects inside the field in the first test was 26.1% of the total weight lifted; the corresponding figures for Gs. were, inside the field 29.7%, outside the field 52.8%). (Besides the tables referred to, see also Plates VIII to XII, pp. 266ff for curves.)

(1) *Conclusion*

The process during the training in Cr.'s case was a building up of a definite idea of the 40-120 gram field, and of acquiring facility in estimating the relative position of any weight within that field; in the case of Gs., a deepening of the impressions of the 40-gram and 120-gram blocks, which were used as bases of judgment. No hard and fast associations between the "heft" of a weight and the idea or expression of its weight in grams could be detected.

No definite associations were built up for probably two reasons: (1) Each series consisted of 17 blocks, which number was probably too great to permit identity[4]; and (2) the "heft" member of the association is exceedingly variable, for besides the influence of the preceding weight, of the preceding estimate, and of the preceding error, it was affected by (1) the height at which the weight is grasped with the fingers, for if it is grasped at the top the block will "swing" and if it is grasped at the bottom it will "topple," in either case being "active" in comparison to the equilibrium of the grasp at the center of gravity, it is likely to be over-estimated; (2) the tightness with which it is grasped, for a loose grasp (a) permits a "pull" on the skin of the finger and thumb, tending to cause over-estimation, and (b) does not permit "coldness" of the weight to be so well sensed, tending to cause under-estimation; (3) whether or not the reagent has been holding his pen tightly in writing introspections; (4) whether the hand is cold or warm, upon which depends the seeming temperature of the block, a cold block appearing heavier than a temperate one; (5) whether the weight is lifted with a jerk, which increases its "heft"; (6) whether it is stopped with a jerk before setting it down, which also increases its "heft"; (7) whether reagent is in "good tone," else all weights seem heavier; (8) and whether one's attention is distracted by counting metronome beats by which to gauge the movement.

This process of estimating weights is therefore a very complex one, and for that reason not best fitted to throw light upon our

[4] That recognition of stimuli diminishes with increase of members in the series, was shown by Lehmann (Ueber Wiedererkennen. Phil. Stud., 5:138).

problem, too many irrelevant factors are possible in both training and tests, to leave our results unambiguous. Witness the fact that more improvement was made in the test than in the training series.

Both of the activities engaged in these two repeated experiments were rather complex, and both included motor elements that come in for their share of the general effect of special practice. These experiments had been devised to learn the relationship of activities with reference to the product of their application rather than to their kind,—they were word-marking and weight-estimating activities among which we have found general practice effect, and have determined the principal factors to be general in nature.

An ideal experiment for determining functional relationship of mental activities, it would seem, should be devised with reference to some well-known and simpler kind of mental activity, with conditions such that identical motor elements do not share responsibility with mental factors for general effect of practice.

2. Experiments on the More Simple Processes

The following two experiments[5] were devised to meet the requirements just mentioned. They employ the same kind activity upon dissimilar stimuli and engage different motor elements. Any transference here of acquired efficiency from a trained to an untrained mental activity must be explained upon psychical grounds alone.

The first experiment was devised to determine the effect of practice upon efficiency in an unpracticed activity; the second, to determine the effect of practice upon facility of improvement in another practiced activity.

a. Sensible Discrimination.

Four reagents were trained in Sensible Discrimination of the intensities of *sound* for 17 days during an interval of 57 days. Each reagent took 40 judgments per day's training.

[5] A brief report of these was made by Coover and Angell in the Am. Jr. Psych., 1907, 18:327, under the title of "General Practice Effect of Special Exercise."

Before and after training they were tested in sensible discrimination of intensities of *brightness,* each test consisting of 3 days' tests of 35 judgments each.

In the training on sound the stimuli were given with a Wundtian sound-pendulum.[6] The method was that of constant changes, Right and Wrong Cases, procedure without knowledge. The variable succeeded the norm in 4 seconds. Some $D = 0$, many $D \gtrless S$ and the larger $D > S$. The number of $V > N = V < N$, and there were about ten values for D in each series. Judgments were made in four categories: $>$, $<$, |||, and? (greater, less, like, and undecided). In a couple of series each day introspections were noted down by the reagent after each judgment; in the remaining series noting introspections was reserved until after each series. Reagents sat in marked positions with backs to the apparatus. This training consisted of very careful work, the data being designed for use in another investigation also.

Efficiencies at the beginning and the end of the training were calculated in per cents of Right cases in the first ten and last ten judgments made upon six values of D. Judgments on $D = 0$ were not included, and 'like' judgments on other values for D were counted an 'undecided.'[7]

Table XIV (p. 270) gives the number of R, W, and U judgments, per cent of R judgments made on each variable, and the per cent of R and U judgments made in each series, at the beginning, and Table XV, at the end of the training on sound.

In the tests on brightness a Marbe color-mixer[8] was used to present the stimuli. Artificial light was used, and the apparatus, including the disc when not exposed, was securely screened in black. Apparatus was also mounted on noiseless bearings. Values for D were chosen after a preliminary series so that there would be some $D > S = V > N$, and some $D > S = V < N$; some $D \gtrless S$ and some $D = 0$. The variables succeeded the norms in

[6] Ill. in double form in Wundt: Grungzüge d. Physiol. Psych. (5th Auf.), III:503.

[7] Cf., F. Angell: Discrimination of shades of gray, etc. Phil. Stud. 19:20.

[8] Illustrated in Wundt: Grundzüge d. Physiol. Psych. (5th Auf.), I:524.

4 seconds and the disc was exhibited 2 seconds. As in the training in sound, a signal was given two seconds before the norm was given. The method was that of Right and Wrong cases, and the procedure was without knowledge. Judgments were given here also in the four categories. Introspections were noted by the reagents after each series of 7 judgments. Each day's experimentation was preceded by a short preliminary series, the judgments of which were not recorded. The order of variables which was used in the before-training test was repeated in the after-training test, and was believed by the reagents to be by chance.

The initial efficiency of the reagents in brightness-discrimination was calculated in per cent of R judgments. Here also the judgments on D=0 were not included, and the 'like' judgments on the other values of D were counted as 'undecided.'

Tables XI-XIII, pp. 269ff, give the number of R, W, U judgments made in brightness-discrimination for each day, number of R, W, U and % of R judgments for each test, upon each variable; and totals for each test, both before and after training.

(1) *Control Experiment*

In order to be more sure of the factors of transference, in case there should be any, a control experiment was devised.

Three reagents were given tests in brightness-discrimination under conditions identical with those obtaining with the regular reagents, except that two instead of three days were taken as a basis for a test. And after an interval, without practice, of 46 days, the tests were repeated.

Tables XVI-XVII (p. 271) give the data from which efficiencies were calculated in the same manner as were the others.

Tables XVIII and XIX (p. 272) compare the results of the two groups of reagents.

(2) *Results*

A comparison of results for all reagents is given in absolute amounts in Table XVIII and in relative amounts in Table XIX.

The per cents in the latter table are all reckoned upon the whole number of judgments in their respective tests which are represented in the tables.

From Table XVIII it may be seen that in the test on brightness-discrimination Aw., a regular reagent, made 66.7% in R judgments before training, and 71.1% after, showing a gain of the difference, 4.4%. He made at the beginning of training on sound-discrimination, 36.7%, and at the end, 51.7%, showing a gain resulting from training of the difference, 15%. In both test and training series he lost in 'undecided' judgments.

Rl., a control reagent, made in the test before the unpracticed interval 68.3% in R judgments, and 63.3% after, showing a loss of the difference, 5%. There was also a gain of 5% in 'undecided' judgments.

Of the four regular reagents, Ya. is the only one who did not show improvement in the test in brightness-discrimination, and he shows no improvement in training on sound-discrimination. He is the only reagent, also, who shows an increase in U judgments in the test series, and he shows similar increase in the training series.

All control reagents show a loss in R judgments[9] in the test

[9] To a statement of this fact in a former report (Am. Jr. Psychol. 18:332) a recent reviewer objects: "But the only use to which this fact should be put is to prove the unreliability of a determination of discrimination of brightness based on seventy comparisons of pairs of grays. To defend general spread of special practice by the doctrine that men possess a tendency to grow worse and worse each week if left without it, is more damaging to it than to attack it." (Thorndike: Educational Psychology, vol. II, p. 400.) This "only use to which this fact should be put," it must be confessed, did not appear so conclusive to the authors of that report in the face of the consistency of the three measurements; they were inclined to let it stand as evidence of *no improvement*. Since some further significance, however, seems demanded, the writer begs to suggest that owing to general fatigue of the reagents, incident to the heavier work of the end of the Semester, or to slightly more difficult conditions for discrimination, incident to the use of another pair of discs in all the after-interval tests, either or both limiting causes applying equally to both groups of reagents, Right judgments were slightly more difficult to make after the interval than before, and, consequently, the real effect of practice in sound-discrimination upon facility in brightness-discrimination is probably *in excess of the amounts reported in the tables.*

An implication, in the same review, to the effect that the use of 'like'

after their unpracticed interval, and two of them show also a gain in U judgments.

(3) *Conclusion*

The transference of improvement in sensible discrimination from training on sound stimuli to efficiency with brightness stimuli would seem to be unequivocally shown by these results.

All the reagents who showed improvement in the training on sound, showed improvement in the tests on brightness. One reagent who took training and did not show improvement in the tests on brightness showed no improvement in his training on sound. All the reagents who took the tests on brightness, but who took no training during the interval between the tests, showed no improvement.

The increase in efficiency in brightness discrimination was not due to practice incident to the tests.

The factors of improvement which have proven to be so general in character are not identical motor elements, for application to the two kinds of data employed disparate senses.

To locate them we will have to resort to an analysis of the

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judgments has clouded our measurement of the capacity for discrimination and has opened the door to increase in Right judgments merely through "taking pains to get a judgment of difference one way or the other" (p. 400), neglects several important considerations. (1) There is no psychological procedure, with the method of Right and Wrong Cases, for determining the capacity for sensible discrimination without the use of the 'like' or 'undecided' judgments; (2) The process of discrimination is itself "taking pains to get a judgment of difference one way or the other," and increase in capacity involves diminishing the number of U judgments in the increase of the number of R judgments. (3) If "taking pains" were to involve *guessing* and not judgment of difference, W cases would increase as rapidly (theoretically) as R cases in the reduction of the number of U cases; whereas, the two trained reagents (Aw. and Cr.) who increased their R cases most also decreased slightly their W cases. (4) A forcing of judgment "of difference one way or the other" would adulterate the R cases, won by "taking pains," with R cases, won by chance, distributed by the usual caprice of variability from theoretical probability, and, consequently, would preclude a measurement of the capacity for discrimination altogether. (5) The use of 'like' or 'undecided' judgments permits the segregation of guesses from judgments, and, consequently, the measurement of capacity for discrimination in per cent of R cases.

process of discrimination which the introspections from the training in sound enable us to make.

Although sensible discrimination is one of the simplest and most fundamental of mental activities, these introspections show it to be quite complex: The attention during discrimination may have an

(A) External reference, in which case the events compared are thought of as external to the body. And the judgment may be the result of (1) Comparing images, or it may be (2) Absolute (without comparison). If it is the result of

(1) Comparison of images, the essential or sound images may be accompanied by images of disparate senses which may control the judgment; they may be

(a) Kinaesthetic, as pronouncing the name of the quality or intensity of sound, or as the feeling of effort necessary to produce the sound, by striking the table with a gavel (Aw. May 5, IV); or

(b) Visual, as picturing the apparatus and the falling ball, as seeing one strike a table with a gavel, as seeing a ball fall, as seeing smoke that would be produced by a percussion cap sounding that loud, as seeing a phonetic illustration of the sound; e.g., "Visual image of a tool bench where I worked a while last summer; the sounds seemed similar" (Aw. May 8, IV). Had a visual image of "an object falling on sounding board" (Aw. May 5, IV). Had a visual image of a "mouth slowly contracting to give a lower sound" (Aw. May 5, IV). "Had a sudden visual image of illustration in phonetics to fit the norm, and thought of it as about three and one-half inches in diameter the short way. When the variable came it took like form, but smaller." (Cr. May 10, II).

(c) The sound images may come with attributes of quickness, sharpness, length, breadth, or distance: "Variable came forth quickly. Had visual image of quick movement" (Na. March 15, II). "Variable had a long-drawn-out sound" (Aw. May 8, II). "Variable is broader sound, that is to say, widely spread" (Na. March 13, II). "Variable comes from farther place," "Variable comes from nearer source," "Variable is a small sound" (Na. March 13, II).

(d) The accompanying imagery may be auditory, as, "Pitch was higher," (Cl. March 15, I). "Lower in pitch" (Cl. March 15, I), or it may seem muffled. Then there are

(2) Absolute judgments made without comparison, and which may or may not be accompanied by the same imagery as the above. "The last one was weak, and I did not compare it with the norm" (Aw. March 13, I). And the final form is

(3) Without localization of the sounds and without accompanying images from disparate senses.

But the attention during discrimination may have an

(B) Internal reference, in which the events compared are thought of as internal to the body. The comparison of norm and variable may be between

(1) Ear disturbances, the ringing or resonance of the sounds as located in the ear. "Had resonance in ear" (Cl. March 13, II). Or comparison may be between the

(2) 'Affects' upon us as a sensing being, and may be accompanied by imagery, as of being struck on the arm with the suggested intensity. "Discriminate 'affects' in head rather than external sounds" (Cr. May 15, IV). Or the comparison may be between

(3) Degrees of reaction to the two sounds, in which the reagent abstracts from the kind of stimuli,—light, tactual, or electrical, would do as well and could be compared with each other,—as the reactions to a flash from a searchlight or the explosion of a torpedo; to the flash of a bicycle-lamp and the slam of a door or a nudge in the ribs. "Seemed to compare reactions to the sounds" (Cr. March 15, I and March 20, III).

This classification of factors involved in the process of sensible discrimination of sound stimuli, as the introspections quoted will serve to indicate, is not merely a logical scheme, but rests solely upon our results. These are some of the factors involved, and they may become controlling factors also, so that had they not accompanied the process, the judgment upon a given pair of stimuli would have been reversed. Without doubt the imagery, whether attention is directed externally or internally to the events compared, is in its quantitative aspect suggested by the real intensities of the sounds. But the imagery may carry the suggesting elements beyond the degree suggested; and it may, if it is not suggested by the intensity but by some other attribute of the sound, counteract and overcome the real relation of the intensities, so as to reverse the judgment. E.g., (1) If the imagery is that of falling balls upon a sounding board, and some quality of the given sound other than intensity suggests the second as being larger than the first although it does not appear to fall from as great a height (suggested by the intensity of the sound), the judgment may be 'greater' in deference to the suggested difference in size; when, had the imagery left the size the same, the judgment would have been 'less' in deference to the height. (2) If the second sound seems to come from farther away than the first, judgment may make allowance for the difference in distance and thereby underestimate the former. Or (3) if the second sound seems muffled, allowance

may be made in the judgment for it and it may be reported as intense as it would have been had it not been muffled. (4) If the second sound seems quicker, sharper, or narrower, its intensity through analogy from pressure or pain sensation may be overestimated. (5) When the ear disturbance is the object of attention, the variation of the pressure of the air in the middle ear due to the eustachian tube opening and closing while swallowing, and of the adjustment of the tympanum, make different bases upon which sounds of the same intensity may be judged to be different. (6) If the 'affect' is the object of attention and the imagery is of being struck, any suggestion that results in having the second stroke fall upon the same or a more tender place might lead to over-estimating its intensity. (7) And our reactions may also be modified by elements of imagery suggested beyond the warrant of the intensities of the sounds, and also by an imagery in which our responsiveness is an essential element, so as to result in modified judgments upon the sounds (reactions).

Besides these various factors which accompany the essential sound-discriminating process by reason of imagery or the direction of attention to the events compared, there are disturbing factors of a general nature, as strong expectation for a loud or weak sound, and the varying intensity of the state of attention. If a loud sound is strongly expected, a weak one may seem weaker; if a weak one is expected, a loud one may seem louder. If the intensity of the state of the attention is sought to be kept at maximum, it will vary greatly, due both to its own rhythm and to the varying subjective conditions upon which it depends.

Improvement seems to consist in divesting the essential process of the unessential factors, freeing judgment from illusions to which the unnecessary and often fantastic imagery gives rise, and of obtaining a uniform state of attention which is less than the maximum: "Judgment does not require strained attention. All are quite certain or satisfactory. Don't see what the process is now—seems automatic," (Cr. May 12, IV).

And uniformity of direction of attention may also result: "Am able to abstract from visual image of the apparatus entirely, and yet refer the sounds to external stimuli. This seems to take the least effort and is more satisfactory," (Cr. May 17, IV). Many of the introspections of the various reagents, near the end of the training, were, "No imagery."

Our conclusion upon the experiment, therefore, is that efficiency in sensible discrimination acquired by training with sound stimuli has been transferred to the efficiency in discriminating brightness-stimuli, and that the factors in this transference of power are necessarily general rather than special in character.

b. Reaction with Discrimination and Choice

Reaction with discrimination and choice is also a relatively simple, definite, and measurable activity, which permits a change in both the motor expression and in the stimuli for the interpolated psychical process.

Identical motor elements were eliminated by employing a different kind of stimulus, and a different form of reaction, although the sense of sight received the stimuli, and reactions were made by the movements of the hands.

The object of the experiment was to determine the influence of improvement in the efficiency of one activity upon the *facility of improvement* in another already practiced. This influence could show itself either in lowering reaction-time in the latter, or making it more regular, or both,—which would be apparent in a practice curve of the tested ability.

Four reagents were trained, during the period of about 40 days (Cl. 46, Al. 41, Cr. 41, Bs. 27), for about 15 days (Cl. 14, Al. 13, Cr. 15, Bs. 11) in card-sorting; during which time about 4000 cards were distributed by each reagent (Cl. 4200, Al. 3800, Cr. 5200, Bs. 4000).

Before the training in the card-sorting the reagents were *trained* for 5 days in typewriter-reaction aggregating about 3000 reactions (Cl. 2900, Al. 2900, Cr. 2700, Bs. 3100) and after

training in card-sorting, for three days, aggregating about 1800 reactions (Cl., Al., Cr., 1800, Bs. 1700).

For the card-sorting we used a cabinet, similar to that illustrated in the Psych. Rev.[10] by Jastrow, which had six compartments (4¼ x 4¾ in.) in which to distribute the cards; and smooth round-cornered cards of buff-colored Bristol-board (77x52 mm.), in the center of which was painted in water-colors a rectangle (12x52 mm.), six colors being used: Red, Blue, Black, and Brown, in a quite heavy shade; and Yellow, and Green in rather a tint than a shade. The cabinet stood at a convenient height, and was entirely covered with black cloth to avoid distraction.

In card-sorting the reagent stood at the cabinet, and held in his left hand a pack of 50 cards, from the top of which he would grasp a card, turn it up sufficiently to see its color on the under surface, and toss it into its appropriate compartment. In about the middle of the training the color labels were removed from the compartments.

The cards were arranged into packs of 50, according to 12 different orders in which each color appeared about as often as another, each preceding and succeeding each other about equally often, and no color recurred with less than two intervening colors. (See Table XX, p. 274, for the orders.)

The assignment of the colors to the compartments was so made that the more apparent spatial relations of the latter would not correspond with the complementary or family relations of the former:

Brown	Green	Yellow
Blue	Black	Red

For the typewriter-reaction we used a No. 7 Blickensderfer typewriter, which was fitted up with a screen through a window in which but one letter could appear at a time. Series of letters were printed with the typewriter and cut into strips which could

[10] Jastrow: Sorting apparatus for the study of Reaction Times. Psych. Rev., 1898, 5:279-285.

be clipped to the 'scale-bar' and moved behind the screen by the 'carriage.' The spacing of the letters in the series and of the typewriter action being the same, the strip could be so adjusted that every stroke on the key-board would automatically present a new letter at the window in the screen.[11]

The various series were made up of 4 letters in such a way that each letter appeared about as often as another, and preceded and succeeded each other and itself about equally often. A letter was added to the beginning of each series the reaction to which was not counted. (See sample, Appendix B. Fig. 4, p. 289.)

In the typewriter-reaction the reagent sat at the machine and, holding his hands in position over the lower bank of keys so that the first two fingers could strike the first two keys on either side of the middle, reacted with the appropriate fingers, to the letters which appeared through the screen, the order of the keys upon which the fingers rested, from the left, being *a-t-e-n*. These were the letters used in constructing the series.

The time of reaction to each letter, as well as of the whole series of fifty was recorded in another room by electrical connections upon a kymograph drum which synchronously recorded seconds from a metronome.

The typewriter itself made records of the reactions which could be inspected for accuracy.

Efficiencies in both card-sorting and typewriter-reaction were calculated in time (seconds) and accuracy (errors) per 100 reactions.

(1) *Control Experiment*

In order to determine more definitely whether improvement shown in typewriter-reaction was due to the training in card-sorting, three reagents were trained in the typewriter-reaction (600 per day) three days before and two days after an interval of 45 days during which no training was taken.[12]

[11] The typewriter thus equipped constituted, in its essentials, Seashore's "Psychergograph" (vid. Univ. Iowa Studies in Psychol., 1902, 3:1-7).

[12] Owing to the imperfections of this control experiment, indicated in the

(2) *Results*

Table XXI (Appendix A, p. 275) gives the time and accuracy of successive hundred reactions on the typewriter for the regular reagents, both (A) before and (B) after training in card-sorting. The italicized figures represent the time of the first hundred reactions of the day's training.

Table XXII (p. 276) gives the daily average time and error per 100 reactions on the typewriter, for the regular reagents, both (A) before and (B) after training in card-sorting.

Table XXIII (p. 276) gives the time and errors of the successive hundred reactions on the typewriter for the control reagents, both (A) before and (B) after an interval without practice; Table XXIV (p. 278) shows the daily averages.

Table XXV (p. 282) gives the time and errors per successive 100 reactions of the regular reagents in the card-sorting training. The time of the first 100 in the day's training is italicized.

Table XXVI (p. 283) gives the daily averages of the same.

These last two tables and Plate XVI (p. 284) show that in the card-sorting training, maximal efficiency was approximately attained. The curves (Plates XVI and XVII, pp. 284-5) show lack of drop and are fairly regular.

From inspection of Tables XXI and XXII and of Plates XIII and XV (pp. 275ff) drawn therefrom, it may be seen how the practice in card-sorting affected the typewriter-reaction. The curves in the case of all reagents are lower, showing shorter reaction-time, and they are more regular, showing less variability.

(a) Errors

But the tables also show in the second training an increase of errors, and the question immediately presents itself as to whether the increase in speed, as shown in the tables and curves, has not been due to greater inaccuracy and therefore no increase

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following pages, a second group of four control reagents were later given practice equivalent to that taken by the Regular reagents. These later results are included in the tables and plates, although it is not possible to spare space for a qualitative discussion of them which would modify slightly their interpretation, because of their decisive contribution.

in efficiency is shown as the result of the card-sorting practice.

Calculation, however, shows that the records most responsible for reducing the time are also those which were made with the lower per cents of error (inspect records in Table XXI B), or, stated differently, that the higher per cents of error correlate with longer time and that the reduction in time has been made in spite of the increase in errors.

From the cord-sorting data (Table XXV) 32 time records, half with no errors and half with four or more errors, per 100 reactions, taken from the data of Al., Cr., and Bs.,—pairs taken from the same days in a manner to eliminate practice effect,—gave an average of 96.5 seconds per 100 reactions, with no errors, and 102.2 seconds per 100 with four or more errors.

From each of the last eight days of training (including three after card-sorting practice) were selected from the typewriter-reaction data (Table XXI), the time of the 100 reactions made with the fewest errors, and the time of the 100 reactions made with the greatest number or errors for the day. The data of each reagent were kept separate and the columns of time and errors averaged with the following results:

Cl.	with	0.06	errors	averages	66.4	sec.	for	100	reactions
	"	2.3	"	"	67.9	"	"	"	"
Al.	"	4.7	"	"	72.0	"	"	"	"
	"	9.9	"	"	73.0	"	"	"	"
Cr.	"	1.4	"	"	65.6	"	"	"	"
	"	5.9	"	"	68.4	"	"	"	"
Bs.	"	2.3	"	"	77.8	"	"	"	"
	"	7.9	"	"	81.6	"	"	"	"

The shorter time being correlated with the fewer errors cannot be accounted for by the possibility that the selected records of the fewer errors have occurred in the latter part of the day's practice and hence would represent a disproportionate amount of daily practice-effect, for the records of the greatest number of errors have occurred later in the day's practice just once more than those of the least number of errors.

Introspections from all reagents support the showing made

by the above data as to the relation between errors and speed: Cr. said, "Made mistake and was bothered thereby," (March 3), "Errors result in confusion and pauses," (March 15). Al. remarked, "the large number of mistakes impedes rapidity, as one is troubled by them," (April 27). And Bs. noted, "mistakes were noticed and caused confusion at the time," (March 20). For these three reagents, errors reduced the speed by confusing or vexing them; but for Cl., by inducing introspection: "I do not care for the making of a mistake in and of itself, but I always pause to think of it and wonder why, and that lessens my attention to the business in hand," (March 1); "The time I spent thinking of a mistake caused a delay," (Feb. 24). Our errors in reacting are thus causes of decrease rather than of increase in speed.

As a matter of fact the errors are not greatly increased as may be seen from the daily averages in Table XXII: for Cl., Cr., and Bs., the increase is less than 2% in the second training in typewriter-reaction; for Al. they increased but 6%, and much of this may be accounted for by the fact that Al. fell more heavily under the unfavorable conditions of the second training, to be noticed later, than did the other reagents.

Some of the increase in errors for all reagents is undoubtedly the result of the same unfavorable conditions of the second training, and some of it is due to the inability to inhibit anticipatory reactions during the rapid rythm of the later practice, which had been inhibited in the slower rythm of the earlier practice. This latter fact is also supported by evidence from introspection, *e.g.*, when reactions were running 73.5 sec. per 100, Cl. said, "Several mistakes inhibited," (March 1), and after practice had reduced the time to 63.3 sec. per 100, she said, "Was running quickly; reaction simply came before I could inhibit making mistake of an *a* for an *n*," (March 10). The increase of errors may not mean that the efficiency of reaction to letters is less therefore, but that facility of reaction has increased to such a speed that anticipatory reactions previously inhibited are now made before they can be inhibited. And the error once made, the speed is retarded.

In comparing efficiencies in the typewriter-reaction, therefore, we may look upon the time record as a satisfactory measure.

For the purpose of learning whether the more unstable associations between the various letters and their proper reactions of the first training were also those of the second training, the errors of the whole period of training in typewriter-reaction were collected and classified. The weaker associations were the same for both periods. For Cl. *e* and *t* were interchanged more than any other two letters, and *a* and *t* were the second pair in instability; for Al. *a* and *t*, and *e* and *t;* for Cr. *e* and *t*, and *a* and *t;* for Bs. *e* and *a*, and *e* and *t*. The card-sorting did not change the peculiarities in the errors of the respective reagents.

There were probably six causes for the errors: (1) Lack of coördination between the letter and its proper reaction, (2) anticipation of a letter in which the reaction took place before the letter was cognized, (3) false cognition of the letter, (4) reaction incited by rhythm without recognition of the letter, (5) misplacement of the fingers on the keys, and (6) raising a fairly automatic process into clearer consciousness and giving the control for the moment to voluntary attention. The 4th and 6th causes enumerated are probably the chief factors in the increase of errors in the second training.

(b) Time

The gradual improvement made in the card-sorting may be seen in Table XXV (p. 282) and on Plate XVI (p. 284). If the first and last 400 reactions are taken for calculating initial and final efficiencies, the training resulted in the following practice-effect, in decrease of time: Cl. 23.5%, Al. 28%, Cr. 22%, Bs. 30%.

The decrease in time in the second training in typewriter-reaction is noticeable in both Tables (XXI, p. 275, XXII, p. 276) and Curves (Plates XIII, p. 279, XV, p. 281).

But inspection of the Tables XXIII and XXIV (pp. 276-8), and Plates XIV (p. 280) and XV (p. 281) of the control reagents shows that they also improved in speed after their unpracticed interval, which suggests that the improvement of the regular

reagents may not have been the result of the training in card-sorting, and invites an examination into the relative facility of improvement.[18]

The curves of the regular reagents, after training in card-sorting, show more improvement in regularity than do those of the control reagents, after the unpracticed interval; they also show the drop in time to be greater (except in the case of Ge., whose curve is quite abnormal). (The line through the curves shows the average of the last day before card-sorting.)

To express quantitatively the relative improvement in speed, data were selected from Tables XXI and XXIII and arranged as is found in Table XXVII (p. 283). The average reaction time per 100 was found for the second and third days of training for both regular and control reagents; with this was compared the average time per 100 for the 4th and 5th days of training, which followed the 2d and 3d in continuous training in the case of the regular reagents, but which came after the unpracticed

[18] To indicate the pitfalls for the statistician who is so completely absorbed in the tables of quantitative results as to neglect the processes involved in producing the results, a recent reviewer may be aptly quoted at this point: "Nothing whatever is needed to account for the improvement in typewriting save the special practice in it" (Thorndike: Educational Psychology, vol. II:407): the average "improvement from the first three days before training to the second three before training is greater than the improvement from the three before, to the three after, training" (*op. cit.*, 406); as though one might expect considerable improvement in this typewriter-reaction after the practice-effect of 3000 reactions which for half of the trained reagents had produced about maximal efficiency. And it is claimed that the control reagents "show no inferiority" to the trained reagents (*ibid.* 407); whereas, as is shown later, the gain during the interval by the only control reagent whose results are comparable to the others is exceeded by the gains of the trained reagents Al. and Bs. and about equaled by the gains of Cl. and Cr. for whom, the averages of the table might have suggested, the reactions had become automatic.

Apart from the unwarrantable aggregating of results so disparate in efficiency (or their place on the practice-curve), and a disregard of the analysis in the text, the reviewer's error is minimized by the fact that by chance only the daily averages were accessible to him. The curves (pp. 279ff) plotted by successive 100 reactions show the facts more clearly, and, if examined with the cautions noted in the text, will, in all probability, clear the authors of the charge that they "endeavor to extract evidence" (*ibid.* 408) of transference. The facts would then seem to prove the conclusions.

interval in the case of the control reagents. The gain made by the control reagent Mn. (7%) is about the same as that made by the regular reagents (Cl. 6%, Al. 0.8%, Cr. 3%, Bs. 8%) in continuous practice. (We disregard Ge.'s data—16%—here as abnormal, for reasons given later, and because they represent series of reactions in which frequent and often long lapses of attention played a great part). Mn. shows gain as a result of the interval. But comparison of the average time per 100 reactions for the last two days before training in card-sorting with the average for the first two days after training shows the regular reagents to have gained more than Mn. after the unpracticed interval (Cl. 6%, Al. 16%, Cr. 5%, Bs. 12%), except in the cases of Cl. and Cr., to be noticed later, in which the gain was about as much.

A comparison of the results in Table XXVII (p. 283) as well as of the curves is misleading unless several things are borne in mind, the principal of which are (1) that the control reagents had trained but three days (Gs. one day) before their unpracticed interval, while the regular reagents trained five days before their training in card-sorting, and for that reason the former would be expected to show more improvement in their second training as a result of practice in that training; and (2) that the control reagents in their training before the unpracticed interval showed comparatively long times from which great improvement in both absolute amount and per cent could be made before much skill would be shown: the last daily average before the interval, for Mn., is as high as the first daily average of two of the regular reagents (Cl., Cr.), and for Ge. almost as high as the first daily averages of the slowest regular reagents (Al., Bs.).

With these facts in mind the comparison of averages in Table XXVII (p. 283) of the curves on Plates XIII-XV (pp. 279ff) discloses *a noticeable improvement in regularity in the cases of Cl. and Cr., and a marked improvement in speed in the cases of Al. and Bs., which is attributable to the training in card-sorting.*[14]

[14] The curves of the second group of control reagents (Bd., Bh., Bs. 2. and Cf.) compare favorably, in time, with those of the regular reagents Cl. and Cr., for whom the processes had become automatic, but they contrast mark-

Some explanation might be offered for the fact that the improvement in speed was not more marked. First, we had sought to determine the effect of training in card-sorting upon the practice-curve of typewriter-reactions. But the typewriter-reaction curve had already attained to records of approximately the *maximum* speed for both Cl. and Cr. Cl. is skilled in piano-playing, and Cr. in typewriting. They trained for five days before the point was reached where the influence of another training should be determined.

On the second day of practice Cl. remarked, "The fingers begin to react at the mere sight of the letters now"; on the third day, "Reacting today is growing more mechanical;" and on the

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edly with those of Al. and Bs., indicating more certainly than was done before the influence of the card-sorting practice. The particularly significant comparable curves are those of the regular reagents Al. and Bs. and the control reagents Cf. and Mn.

Some slight additional evidence in support of the hypothesis of a functional relationship between the two kinds of reaction we have employed is afforded by an auxiliary experiment in which the influence of practice in typewriter-reaction upon card-sorting was tested. The four reagents, mentioned above and on pp 52f as the second group of control reagents, served in this experiment as the regular reagents, practiced by 4000 typewriter-reactions each. Immediately before and on the last day of that practice they sorted at one sitting four packs of 50 playing-cards into four compartments labeled Diamonds, Spades, Clubs, and Hearts:

D	S
C	H

The intervals between sortings were 58 days for Bd., Bh., and Bs. 2, and 44 days for Cf.

Two control reagents, Cn., and Sn., sorted four packs each, before and after intervals of 56 days and 53 days respectively.

Both groups of reagents had had extended practice throughout the preceding semester in sorting playing cards by suit according to a different method. They sorted in piles upon a table instead of into compartments, and sorted to the place of the preceding card instead of to the place of the card held. All were therefore nearer practiced condition in sorting cards before the interval than after it, which may account for the loss of the control reagents.

One of the regular reagents (Bs. 2) was suffering from a severe cold on the day of her final sorting and shows no improvement; the others seem to have carried over some practice-effect from typewriter-reaction to card-sorting, as may be seen from Table XXVIII (p. 286) and Plate XVIII (p. 287).

fifth day, "Reaction to the sight of the letter is so automatic that I can think of other things as I operate. . . . During the reaction attention was not well concentrated at times because I was thinking of the influence of thinking about your rate of speed upon your speed." Reacting had obviously become automatic. And Cr. on the third day of training remarked, "reacting is becoming very mechanical." Hence in these two cases we have determined the effect of training in card-sorting upon typewriter-reaction after it had already been trained to a high degree of automatization. The cases of Al. and Bs. are different. Neither is skilled in typewriting, although each had used a typewriter, and Al. remarked, "No application of former practice with the typewriter,—motion a new one," (Feb. 24). They did not speak of the process as being automatic before the card-sorting began,—and they show greater practice-effect.

Another reason may be given for the reduction in time not being more marked. The second training on the typewriter was taken by the Regular reagents during April 26-28 while everybody was rushed with work preparing for the closing of the semester, and meeting the many social duties coming at that time, all of which occasioned general fatigue in at least three of the reagents. Cr. took the first day's work in the second training so late that the room was dusk and his attention was almost wholly directed to the perception of the letters: "Had to strain to perceive the letters; this part of the process demanded all the attention; some errors are due to mistaking at first the letter outline" (April 26). Al. was doing heavy work day and night: "Reagent very tired, cannot hold attention; up till 1 o'clock preceding night busied with exhausting and harassing work" (April 27). And Cl. noted, "Have been up late for six out of seven nights past and feel somewhat below normal."

But the most marked effect of card-sorting on the typewriter-reaction is shown by introspections. On the first day of the second training Cl. remarks, "Sight of letter produced the reaction movement without my thinking of my fingers and not at all of the sight of the keys" (April 26). Al. remarked, "No

headache, no nausea, as before card-sorting," "Much easier than at first"; "General background of feeling is probably not unlike that of card-sorting, but I did not think of the card-sorting during the trial" (April 26). Cr. said, "Process was surprisingly automatic and was accompanied with ease" (April 26); "seems more automatic than ever before, and even more so than the card-sorting. I do not pay slightest attention to the fingers or the keyboard when the process is going best . . . it appears that the old associations have not only not been interfered with by forming new ones in card-sorting but that they have become firmer and action upon them more ready and automatic than it was before or than it was in card-sorting," (April 27). On the last day of typewriter-training before card-sorting began, Bs. remarked, "Pauses between letters caused by having to think which finger I should put down," and on the first day after card-sorting, "Seemed more natural than I thought it would," and the next day, "Seemed more natural to react today, demands less attention, tendency to become automatic."

The introspections of the control reagents, none of whom was familiar with typewriting, show that while some ease and facility were experienced before the interval, reaction afterwards seemed unexpectedly "difficult" and "unhandy:" Mn. stated in the second training that "Reacting seemed difficult," "Seemed to have to stop to think which finger was to react to the different letters." Ge. in the training before the interval said, "The reactions are becoming more automatic," and afterward, that he "looked at letters not knowing what to do" and that "combination of letters here was particularly unhandy," The interval without practice resulting in a feeling of discomfort and difficulty, strengthens the point of the preceding paragraph that the training in card-sorting is the cause of the increased ease and facility experienced by the regular reagents in the second training in the typewriter-reaction.

(3) *Conclusion*

We conclude, therefore, from the results of this experiment, that training the activity of reaction with discrimination and

choice by sorting cards into compartments has increased the facility of the same activity in both speed and regularity in typewriter-reaction (a) noticeably in regularity in two cases after the latter had become automatic, and (b) markedly in speed in two others in the course of practice.

The cause of transferred facility could not have been identical motor elements. In the typewriter-reaction the eyes rested sharply fixated upon one spot on the screen while the fingers, with coördinating wrist and forearm movements, tapped down the keys, accessory muscles being mainly used; in the card-sorting reaction the eyes moved from the cognized colors on the cards about over the compartments of the cabinet or followed the movement of the hand and fixation was nowhere so intense, while the right arm contributed most of the movement in grasping the cards, turning up the under color-surface, and casting them into the compartments, using mainly fundamental muscles.

Neither could the cause have been habituation to the stimuli, for they were different in character: one being a small symbol (form) and the other a comparatively large rectangular surface of color.

Nor was the cause identical associations between stimuli and reactions.

According to the introspections of the regular reagents on their card-sorting training, the process of reaction is variable. At the beginning of training they matched the color of the cards with the labels on the compartments then to increase speed a system of mnemonics is employed designed to form associations in the mind between a compartment and its color; this system then goes through a process of mutation—becoming abbreviated, changed in part, or supplemented,—or is superseded by another; finally, through repetition reactions to particular compartments become coördinated with their respective colors and are made directly, free of the system except in cases of emergency. Synchronously with the growth of these coördinations, adventitious processes, as pronouncing the color when cognized, movement and strain of the whole body, and disadvantageous movements of the hand, decrease to a minimum.

According to the introspections of both the regular and control

reagents on the typewriter-reaction, the process of reaction goes through precisely the same stages, except that it starts with a system of mnemonics, and systems are superseded more often. No two systems are alike. But all finally give way to the direct reaction which has been coördinated with its letter. Adventitious processes, as pronouncing letters upon cognizing them, visualizing keys, fingers, on their order, likewise decrease to a minimum.

These two processes so summarily described are necessarily related to their particular stimuli and their appropriate reactions, and seem therefore fairly independent of each other. But there is one *common factor* already apparent: *The habit of stripping the essential process of its adventitious accessories.* This is one of the causes of transferred facility, and we shall notice two others.

Introspections also state that in any one series several systems of mnemonics may be operative; there may be some direct reactions due to coördination of stimulus and reaction, some due to a kinaesthetic image of recent reaction; that in one part of the series one stimulus causes difficulty and in another part another stimulus; that some stimuli are harder than others throughout the whole series. Improvement here seems to consist in resolving the reaction process to a single type, except in so far as reactions become direct, and to attend somewhat more closely to the difficult stimuli until their reactions become as ready as those to the other stimuli; but also, not to confine attention so closely to the troublesome stimuli that their reactions anticipate other stimuli and cause errors thereby.

Again, introspections and records show that even after a mnemonic system has been successfully applied and has served to bring stimulus and reaction to a fair degree of coördination, lapses of attention occur during which the "mind is a blank," and the drum records abnormally long reactions. Improvement here consists in keeping attention upon the matter in hand so constantly that irrelevant stimuli are unnoticed.

We find, therefore, the causes of the transference of facility to be (*a*) *the habit of reacting to a stimulus without being delayed by prominent kinaesthetic, acoustic, and motor accom-*

paniments of recognition, through gradually dropping these out of the process, or reducing them to a minimum; (b) an equitable distribution of the attention to the various possible reactions so as to be about equally prepared for all; and (c) the power of concentrating upon the process through a whole series to such a degree as to eliminate distraction.

II. PRINCIPALLY QUALITATIVE

Experimentation thus far had pretty well established the fact of the general effect of special practice, but there is not yet a general agreement in the interpretation of the results, as to extent and causes of transference of practice-effect; and in almost all investigations there stand out anomalous cases which remain unexplained.

Most of the introspective analyses of practice effect show it to be extensively general in both positive and negative influence, but Sleight argues from the paucity of 'significant' values in his tables that it is narrowly specific. Ebert and Meumann found training-effect to be permanent for at least three months; Sleight interprets his evidence to indicate that "the effects of both 'direct' and 'indirect' practice are usually not permanent."[15] Fracker

[15] *Op. cit.*, p. 451.

The effect of practice is found to be more permanent than the opposing factors of interference (Bair: The Practice Curve. Psych. Rev. Mon. 1902. 5:No.2, and Bergström: An experimental study of some of the conditions of mental activity. Am. Jr. Psych., 1893-4, 6:272) and fatigue (Kraepelin: Die Arbeitscurve. Phil. Studien., 1902, 19:476; also, A measure of mental capacity. Pop. Sci. Mo., 1896, 49:760), and although some studies show that the greater part of it is soon lost (Kraepelin: *loc. cit.*), it may endure for a long time:

Kraepelin found that two hours of practice in adding left noticeable traces three months afterward, and that the effect of 17 presentations of associations was perceptible 1⅓ years later (*op. cit.* S. 476).

Ebbinghaus (Grundzüge der Psychologie, 2te Auf. Bd. I. S. 633) saved 7% in number of repetitions upon relearning stanzas from Byron's Don Juan after an interval of 22 years; and 20% after an interval of 17 years.

Bourdon (Recherches sur l'habitude. Année Psych. 1901. 8:327-340) found that skill acquired in marking out letters in a page of print dropped

found the greatest cause of improvement and transference in memory of simple sounds or shades, to be the development and carrying over of representative imagery of a very simple and definite type; while Ebert and Meumann found that in training on non-sense syllables the use of, and dependence upon, representative imagery of all kinds dropped away. And Fracker is inclined to oppose his results to those of Coover and Angell because the latter pointed out the function of representative imagery in the processes of discrimination, and of reaction with discrimination and choice, to be respectively a distraction, and a temporary but probably a necessary means of effecting automatic coördination between stimulus and reaction.

Almost all investigators conclude that when transference of practice-effect takes place, it varies in amount with the similarity of either the material or the method of the tests to the practice, and there seems no reason why one should not hope for this law to be finally established. But, so far, either the ways in which practice and training may be similar must be multiplied and further defined or the exceptions to the law appear, upon inspection of the results, to be the rule. A few of the anomalies, for the purpose of illustration, follow:

From the results of Thorndike and Woodworth, we note that the average gain in training on estimating areas was about 52%, that tests on the same form within the field of change of area in training yielded an average of 61%; but that above the field, same form, 16%; while above the field, different form, 51%. Again, one reagent (W) in training on estimating

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very little during a rest of 236 days; and that most of it remained at the end of a rest of seven years.

Book (Psychology of skill, with special reference to its acquisition in typewriting. Univ. Mont. Bull. 1908. 53:75) found effect of practice in typewriting to persist after a rest of one and a half years.

Swift (Relearning a skillful act: An experimental study in neuro-muscular memory. Psych. Bull. 1910. 7:17-19) found skill in tossing balls to be retained 275 days; and that it could be rapidly regained after an interval of 6 years. Skill that had required 42 days' practice to attain was regained in 11 days. In the last "try" of his test he exceeded his former skill, in number of catches, in the ratio of 1600:1051.

weights made 49% improvement, while estimating objects within the field of training he made 62%.

In Ebert and Meumann's research we found improvement in 'immediate memory' for non-sense syllables (the training material) to be 20%; while for numbers it was 29%, and for letters, 36%; if the grade of memory at "two-thirds correct" is considered, for non-sense syllables it was 49%, but for numbers 56%. In 'complete learning,' for non-sense syllables it was 61%, for poetry 20%, but for prose it was 43%. One would surmise that the more arbitrary sequence of words in poetry would make it more similar than prose to the training. Retention after 24 hours, of non-sense syllables, was improved 45%, but of optical symbols 49% and of prose 67%.

From Fracker's research we found the average gain in training upon memory of sounds 21%, and the average gain upon the test on grays 36%, seven of the eight trained reagents gaining more in this test than in the training. Reagents exceeded their training gain in other tests also: on nine tones, 4 reagents; on nine grays, 4; on four pitches of a tone, 2; on geometrical figures, 3. From the monograph, we learn that F. S., "a graduate student in psychology, who was trained in many forms of experiment" (p. 64), trained on sound 8 days, taking four sets of 75 sounds each, per day; he started at 70% reproduced elements, and finished with 40%, while three of the other reagents finished near or above 90%. In spite of his inverted practice curve he shows gains in his tests, however. If his most efficient imagery was auditory, as it seems from introspections upon training, and his test on four pitches (p. 82), to have been, how did he by a change of method make his greatest gain (26%) upon the four grays, and how make so little gain upon nine tones (1%), and upon nine numbers (4%)? Another reagent (H. C. E.) who developed during training a very definite visual system of imagery involving four positions, made more gain upon the square of geometrical figures (35%) than he did in training (27%), and less upon the four pitches (23%) than upon the figures.

From Sleight's research we noted that of the three trained

groups of children, but one group showed improvement in the tests more similar in material to their training and that according to the two sets of data there are scarcely any correspondences between the 'significant' values of the children and the adults.

It is probable that the conflicting nature of results rests largely upon differences in detail of experimental procedure: the kind and length of training, the kind, length, and number of tests, and the manner of scoring and comparing results.

The paucity of 'significant' values in Sleight's tables may indicate merely that (a) the training-effect of practice on the trained groups is but slightly greater than the training-effect of other school work upon all the reagents; (b) statistical treatment smothers the facts: *e.g.*, with a probable error of 16, and a difference-score of 53, a 'significant' value would necessitate a gain of 30 points in the second test over the first when the average score in the first was but 66.8 (Group 2, on points),[16] which means that if the gain in the second test is not about half the initial capacity it cannot be considered really significant; (c) the probable error is unduly large, by reason of widely differing initial efficiencies of individuals (in the test on points initial efficiencies ranged: for School X 27-93, for School Y 32-129, for School Z 23-132).[17] Where individuals differ so greatly in capacity, we learn in following experiments, they are not doing the same thing, not applying themselves to the same kind of work.[18]

The permanence of training-effect found by Ebert and Meumann may, as Sleight thinks, be due to the inadequacy of the per cent method of expressing results, or to greater ease of the later tests; again, it may be due to the rigor of the training, which greatly exceeded that of Sleight's reagents.

The usefulness of representative imagery found by Fracker may be largely due to the small number of separate units of

[16] *Op. cit.*, Tables, pp. 413-417.

[17] *Idem*, Table I, pp. 410-411.

[18] Hollingworth (Individual differences before, during, and after practice. Psych. Rev., 1914, 21:8) upon the basis of low correlation in early practice changing to high correlation in later practice, concluded that in the early trials he was not "measuring the same thing with all performers."

which his series were made up, and to the simplicity of the stimuli, both of which conditions were foreign to the training material of the reagents of Ebert and Meumann.

The anomalous cases may be due to inadequate methods of comparing results or to a radical change in the reagent's processes.

If the initial capacities of two reagents are not about equal, and the improvement is made through increasing the number of units of work within a given time, not only will the difference-score of the lower capacity have the advantage of the higher, because of more room for improvement, but expression in per cent of gain will exaggerate this advantage. (When the score is reckoned in decrease of time taken to perform a given amount of work, the expression of the score-differences in the form of per cent, of course, compensates in a measure the advantage of the low initial capacity).

That some anomalies are the result of radical changes in the reagent's processes may be illustrated by a few cases reported in experiments some pages back (pp. 38ff.). In the word-marking experiment Gs. made his lowest gain on *s-p* words (15%)[19] when the material was similar to that used in the training, while on material different from the training he averaged 30%—in spite of the fact that the per cent form of expression tended to reduce the inequalities among initial capacities. Upon inspecting the table[20] we note that his initial capacity was about twice as high as in the other tests. Introspections state that his method of marking *s-p* words in the first test was radically different from his method of marking other words:[21] he took *p* for the cue and ran his eye along under the line for the projecting stem; he took advantage of the form of the letter to turn from hunting letters to hunting a certain rare but easily recognizable projection. In the second test he hunted for letters. His low gain in marking out *l-o* words from manuscript pages was due to a similar change in process:

[19] *Vid.*, Table I, (Appendix A., p. 259).
[20] *Vid.*, Table II, Plate I, (Appendix A., pp. 260, 261).
[21] P. 38.

he sought above the line for the loop of the *l*, to the first test. Cr.'s low gain on *s-p* words was owing to the same cause.

In the weight-estimating experiment, Cr.'s great loss on objects outside the field was owing to greatly over-estimating the weights of two of the ten objects—a bottle of muscilage and a volume of the Psych. Rev.[22] He used in both tests on this series of objects, as a basis of judgment, a kinaesthetic image of a 1000-gram weight accidently handled some days before the first test, and it served more poorly for the second test since it was more vague,—a process very different from his estimation of the other series of objects.

Large differences in an individual's results appear to be due to a radical change in processes and for that reason do not seem properly comparable with his other difference-scores—the scores in question do not measure the same kind of work. Whether great variation in initial scores of different reagents make them, for the same reason, non-comparable, remains for analyses of processes to determine; if they are non-comparable, no other statistical device is likely to prove more satisfactory in comparing them than the absolute or the per cent form.

Evidently we need to know more about (a) the extent of variability in processes, with a single reagent and between different reagents,[23] who set themselves to the same objective task;

[22] Table X, (Appendix A, p. 265).

[23] Contributions to individual psychology show us that individuals may vary tremendously in their mental processes, *vid.*

Binet et Jassey: Étude de psychologie sur les auteurs dramatiques. Année Psych., 1895, 1:60-118.

Binet et Henri: La psychologie individuelle. Année Psych., 1895, 2:411-465.

Toulouse: Enquête medico-psychologique sur les rapports de la supériorite intellectuelle avec la névropathie. 1896.

Oehrn: Experimentelle Studien zur Individualpsychologie. Psych. Arbeiten., 1896, 1:92-151.

Binet: L'Étude expérimentale de l'Intelligence. Paris. 1903.

Sharp: Individual psychology: A study in psychological method. Am. Jr. Psych., 1899, 10:329-391.

Whitley: An empirical study of certain tests for individual differences. Archives of Psych., 1911, 3: No. 19.

Also the studies which attack directly the problem of the Diagnosis of mental imagery (like those of Secor, Segal, and Fernald) or which make

(b) the causes of this variability; and (c) its effect upon the scores. We might then be able to determine more precisely how training affects the processes engaged in the training, how training-effect affects the test-capacities, and how these facts may be properly expressed in quantitative terms.

To this task of qualitative analysis we set ourselves in the following two experiments, and at the risk of tedium we report on both tests and training as fully as our introspective data permit.

1. Experiment on Attention. (Variability in Mental Processes).[a]

In order to give greater opportunity for variability and for functional relationship of processes to appear, it seemed desirable to extend more than is usual the variety of tests and training; the variability for the large number of tests and different kinds of training could be worked out in detail and thus furnish a basis for a critique of this type of experiment, while functional relationship, at the risk of not being found at all, might be detected where it is scarcely expected, thus revealing some new causes for general effect of training, both positive and negative.

Fortunately there is an excellent opportunity for organizing a number of variously related tests into this standard type of experiment. In many of the discussions psychologists have attributed the general effect of special practice, in part, to training in attention.[24] In the want, as yet, of any direct method of

an analytical inspection of the memory process (like those of Kuhlmann, Gamble, Cohn, Sybel, Wreschner, and Müller), as well as the early work in which the concept of "imagery types" was originated and developed (Fechner, Galton, and Charcot).

[a] Performed during the year 1910-1911.

[24] *Vid.* Angell, J. R.: The doctrine of formal discipline in the light of the principles of general psychology. Ed. Rev., 1908, 36:8.

Aall: in review of Coover and Angell. Zeit. f. Psych., 1908, 48:303.

Müller: Zur Analyse der Gedächtnistätigkeit u.d. Vorstellungsverlaufes. Zeits. f. Psych., 1911. Erg. Bd. S. 244. Ebert und Meumann (*op. cit.* 205), Fracher (*op. cit.* 95), Sleight (*op. cit.* 442-3). Stumpf (Tonpsychologie, 1:81).

measuring attention,[25] lies our opportunity. If attention can be measured at all,[26] and, in view of the fact that it is often practically gauged by casual observation, it seems reasonable to hope that it can, it must be measured by the product of such mental activities as are known to depend in the highest degree upon the attentive state. Such activities are sensitivity, sensible discrimination, reproduction, and voluntary activity;[27] and a large number of fairly standard tests are at hand which may be used to measure them.

If we get the initial capacity of a number of reagents in a number of these tests, we may be said to have obtained indirectly a cross-section of their initial capacity in attention. Then, if special training is given to some of them, and the tests are given to all of them again for a final measure of attention, our experiment will conform to the type usually employed in our field of investigation.

Although we are for the moment assuming that attention is a simple and uniform state of consciousness, we may, perhaps, have to recognize (a) that there are phases or 'moments' of attention[28] such as degree of concentration, quickness of adaptation, and duration of concentration; and (b) that individuals might possess (1) different types of attention,[29] such as broad or narrow spanned, alert or sluggish, visual or auditory or motor, or (2) different types of consciousness,[30] such as dual or multi-level.

We may then, provisionally, call this an experiment on attention; our chief aim being to learn the extent and causes of variability in processes engaged in tests and training of widely different kinds, incidentally, to trace through introspective

[25] In 1893 Külpe wrote: "The discovery of a reliable measure of the attention would appear to be one of the most important problems that await solution by the experimental psychology of the future." (Outlines of Psychology. 1901. Sec. 73.2). And in 1908 Titchener said: "The discovery has not yet been made" (Lectures on the Elementary psychology of feeling and attention. 1908, p. 276) which still remains true.

[26] For present methods of measuring attention see Titchener (*ibid.* 276ff), and Pillsbury (Attention. ch. VI.).

[27] *Vid.* Külpe: *op cit.* Sec. 73.

[28] Chase: Some aspects of the attention problem. Ped. Sem., 1909, 16:281.

[29] McComas: Some types of attention. Psych. Rev. Mon., 1911, No. 55:55.

[30] Geissler: The measurement of attention. Am. Jr. Psych., 1909, 20:473ff.

analysis the functional relationship between sets of processes varying more or less from the training in kind, when applied to tests varying more or less from the training in material; and in case we get sufficient data which may be justly compared, we may be able to determine whether improved attention is a cause of general effect of special practice.

a. The Tests

The following tests[31] were chosen because of their dependence upon attention:

I. Reaction
- 1. Simple sensory to sound .... (50) 1
- 2. Compound
  - a. With discrimination
    - (1) Marking out small a's .... (100) 2
    - (2) Marking out o's .... (100) 3
  - b. With discrimination and choice
    - (1) Card-sorting .... (200) 4
    - (2) Typewriter-reaction .... (200) 5
    - (3) Controlled reaction .... (50) 6

II. Sensible discrimination of sounds .... (90) 7

III. Reproduction
- 1. Unequivocal (Rote memory)
  - a. Successive presentation
    - (1) Memory of sound intensities .... (50) 8
    - (2) Memory of consonants .... (50) 9
    - (3) Memory of Arabic numerals .... (50) 10
    - (4) Memory of visual signs .... (10) 11
    - (5) Memory of associated pairs .... (50) 12
  - b. Simultaneous presentation
    - (1) Learning 12-letter-rectangles
      - (a) Free .... (10) 13
      - (b) With distraction .... (10) 14
- 2. Equivocal—Word-completion .... (10) 15
- 3. Free—2-minute trains of ideas .... (3) 16

IV. Extensive threshold of visual attention
- 1. Free .... (15) 17
- 2. With distraction .... (10) 18

V. Maximum voluntary activity—tapping .... (5 30″) 19

(The figures in parenthesis indicate the number of reactions, memory units, or experiments, in the test.)

[31] How these tests are related, in method or material, both to laboratory work and to standard mental tests, is indicated by some representative bibliography given with the discussion of Test Results (pp. 106ff.).

These tests were taken by 10 reagents, 8 of whom took training between the first and final series which were separated by an interval of 55 days. The first series of tests occupied 12 days during a period of 36 days; the second, or final, 10 days during a period of 21 days. Each pair of tests was separated by an interval of about 66 days.

The pairs of tests were also taken by two reagents of a group of 21 control reagents. There were thus two sets of control reagents: The two who took all the tests, and the 21 each of whom took only one pair or a few pairs of tests.

The conditions of the final tests were as nearly identical with those of the first as circumstances permitted. The material was also identical with the exception of the Tests 4 and 5, in which the orders of the symbols were changed to avoid learning sequences of reactions.

Of the reagents who took training, 7 had training in advanced psychological laboratory work; 1 had no training. Of the first group of control reagents (2), 1 had training. Of the second group (21), one was taking elementary laboratory work; the others were in a class of general psychology. The students of this second group represented nine departments in the university; there were two graduates, eight seniors, five juniors, and six sophomores. On the whole they ranked younger than the other two groups.

b. The Training

During the 55-day interval between the tests, two reagents (Mn., Le.) took training 18 days on Test 17; 25 12-letter-rectangles were presented daily, making in all 450 experiments each. Two reagents (Rt. and Sl.) took training 18 days on Test 13; 20 12-letter-rectangles were presented daily, aggregating 360 experiments each. One reagent (Ly.) took training in simple reaction to sound for 11 days, 1100 reactions in all. (Le., who took training on test 17, also took training in this simple reaction to the extent of about 500 reactions). Two reagents (He., Cr.) took training on memory schemes for about 14 days.

And one reagent (Al.) took training on Test 17 for 8 days, almost consecutive, to the extent of 200 experiments.

In the training as in the tests introspections were written or dictated.

c. Apparatus and Procedure

(1) *Reaction to Sound*

For simple reaction to sound, the Morse key (set at a tension of 100 grams, and an amplitude at the button of 3 mm.) was released by raising the index finger of the right hand. The reagent was instructed to lay the arm and hand on the table forming a hand-rest by folding in the fingers and extending the thumb and to give a stimulus-direction to attention. No apparatus except the key was visible to the reagent, the Wundtian sound-hammer[32] for presenting the stimulus being located a meter to the right and back of his head. The whirr of the chronoscope could be heard from the adjoining room and acted as a second signal. A "ready" signal was called at irregular intervals from two to five seconds before the stimulus was given. After reaction the reagent noted introspections and called "ready" for the next experiment; he was practiced before the experiment and the first three reaction-times of the first daily series, and the first reaction-time of the other series, were discarded. The Hipp chronoscope was tested daily with a fall-hammer[33] and its MV. found to be less than 1.5 sigma. Twenty valid reactions were taken on the first day; 30 on the second.

For each series of 10 reactions were found the (a) arithmetical mean, (b) probable error, (c) standard deviation, (d) PE of the standard deviation, and (e) coëfficient of variation,[34] besides the (f) MV. and the (g) relative variation.[35] These were averaged for the five series of the test. Inspection showed, however, that owing to the increased sensitiveness of those

[32] Illustrated in Wundt: Grundzüge der Psysiol. Psych (5 te Auf.), III:503.
[33] Illustrated, *ibid.*, S. 397.
[34] *Vid.* Titchener: Experimental Psych., Vol. II, Pt. II, p. 361.
[35] *Vid. ibid.* Pt. I, p. 181. r.v.=MV.x100/M.

measures which rest upon the square of the deviations from the mean, over the MV. and the r.v., for occasional large deviations (yet not sufficiently large to discard),[36] the former possessed no advantage over the latter which alone were consequently retained.

(2) *Marking Out a's*

The reagent was instructed to mark out all the small *a*'s between the pen marks across a printed page. The material consisted of page 12 of Horace Davis' Phi Beta Kappa address on Vocational Training, delivered at Stanford University, May 8, 1909. Between lines 2 and 30, inclusive, there are 100 small *a*'s. The page was placed before the reagent right side up, covered with a screen which was removed at the moment the stop-watch was started for timing the test. Introspections were written after the test.

The Efficiency Index was computed according to Whipple's formula.[37] Since no letters were wrongly crossed out, the Efficiency Index became the "time per 100 reactions."

(3) *Marking Out o's*

Page 13 of the same material as above was used for marking out small *o*'s, of which there are 100 between lines 1 and 30 inclusive. The page was placed before the reagent *inverted.* Further procedure as above.

Tests 2. and 3. were taken in a single sitting.

(4) *Card-Sorting*

A Jastrow[38] cabinet of six compartments, and four packs of 50 cards (6 x 8.5 cm.) were used for card-sorting. The cards were not glazed but were smooth and fairly stiff. In a central position at one end they bore a printed device (14 mm. in

[36] Times with deviations greater than 4xMV. were discarded.

[37] Whipple's Manual (1st ed.). 260f. E=T/A, A=c-w/c+o, where T=time, A=accuracy, c=letters crossed out, w=letters wrongly crossed, o=a's omitted.

[38] Jastrow: A sorting apparatus for the study of reaction times. Psych. Rev., 1898, 5:279ff.

diameter),[39] chosen with the design of prohibiting verbal classification, which was turned thru 0°, 90°, 135°, 180°, 270°, and 315°, to make the six classes of cards to be discriminated. The labels on the compartments were so arranged as to avoid easy classification. After reading typewritten instructions[40] the reagent took a standing position at the cabinet, informed the experimenter that he was ready, and started with the experimenter's signal "go." The time of each pack was taken with a stop-watch. Introspections were written after each pack. Two packs were sorted on one day, the remaining two on another.

Efficiency consisted of the average time for the four packs in each test. The errors were very few and were fairly constant in each reagent's work.

(5) *Typewriter-Reaction*

Reactions were made with the first two fingers of the two hands to the four letters *a, t, e, n,* as they appeared automatically through a screen on the (Blickensderfer) typewriter. Reaction to one letter brought the next into view. The four series were composed of 50 letters each, so arranged that each letter preceded and succeeded itself and each other about equally often.[41] Opportunity was given for writing introspections after the 2d and 4th series. The typewriter was connected in circuit with a marker which recorded the reactions, upon a smoked drum, beside a synchronous seconds-record furnished electrically by the laboratory clock.

Efficiency was calculated from the kymograph records in seconds per series of 50 reactions. The average of the four records constituted the score of the test. Accuracy was checked by the record of reactions made by the typewriter, and since it was found to be uniformly high, it was not used to modify the time-score.[42] The four series of reactions were taken at a single sitting.

[39] See Appendix B, Figs. 1 and 2 (p. 288) for reproduction of device and arrangement of compartments in cabinet.

[40] Appendix B, Fig. 3 (p. 288).

[41] Appendix B, Fig. 4 (p. 289).

[42] No reagent made more than 3 errors; the general average was 1.6 per series.

(6) *Controlled Reaction*

Reaction was made with the first two fingers of the left hand the first three of the right hand on the typewriter. The respective fingers represented, from left to right, *Poets, Philosophers, Statesmen, Scientists,* and *Musicians.* Ten familiar names of each class[43] were arranged into 10 favorable series[44] and were pronounced singly[45]. Time was taken with a stop-watch which was selected from a collection of 10 for its favorable action. A day or two before the experiment the complete list of names was read by classes to the reagent to determine whether any were unfamiliar, and, if so, to learn them; and before the experiment he was drilled upon the class-finger coördinations until he was sure that he knew them. Introspections were written after the fifth and the last series. After the test, free reactions were taken to one-, two-, and three-syllabled names, in which all the five fingers were used, not in regular order, to determine how much variation in time might be owing to length of name.[45a] The test was taken in a single sitting.

Efficiency was calculated in terms of time alone; the mean of the 50 reaction-times, and the mean for each class.

(7) *Sound Discrimination*

Nine intervals of intensity[46] (including D=0) were given with a Wundtian sound-pendulum.[47] The upper and lower intervals could almost always be clearly cognized. The time interval between norm and variable was about three seconds, between pairs about 12 seconds, and between series of nine

[43] Appendix B, Fig. 5 (p. 289).

[44] Appendix B, Fig. 6 (p. 289).

[45] With one exception: Cr. reacted as rapidly as possible to each half of the 10 series, which was presented simultaneously to his vision.

[45a] The general averages for all reagents were: .69, .73, .81; making a difference of 0.12″ between the shortest and longest names. Since the long names were distributed throughout all series, no reference to this is made in the discussion of results.

[46] Appendix B, Fig. 7a (p. 290).

[47] Illustrated in Wundt: Grundzüge d. Physiol. Psych., I:511. Ours is the single pendulum type.

judgments 2.5 minutes. Ten series[48] constituted the test. Procedure was without knowledge and by the method of Right and Wrong cases. The reagent sat facing dark screens, with his back to the sound-pendulum which was about 5 meters distant; he recorded his judgment upon the intensity of the second sound (always the variable) by the use of symbols[49] signifying "greater," "less," "like," and "doubtful." Introspections were reached between series and after the test all of which occupied the hour.

Efficiency was calculated in terms of Right judgments and the 'Difference Limen.'

(8) *Memory of Sounds*

Five series[50] of 10 sounds each were constructed with four easily distinguishable sounds (relative intensities: 0.12, 0.8, 2.1, 5.)[51] produced on the sound pendulum. Members of a series succeeded each other at the rate of one second; an interval of 2.5 minutes was given between series. The reagent sat 5 meters from the sound-pendulum with his back toward it, and recorded the sounds in terms of 1, 2, 3, 4, in the order of their intensity. He was familiar with the sounds of the instrument since this test followed the test on Sensible discrimination, and in a preliminary practice he was drilled until he could name instantly any of the sounds produced in irregular order. The reagents recorded in ruled forms; and wrote introspections between series and after the test.[52]

Efficiency was calculated with Spearman's "Footrule for scoring the memory test."[53]

[48] Appendix B, Fig. 7b, (p. 290).
[49] Appendix B, Fig. 8, (p. 290).
[50] Appendix B, Fig. 9, (p. 290).
[51] From Fechner: Psychophysik., I. S. 181.
[52] This holds true for all the succeeding tests on memory.
[53] Whipple's Manual (1st ed.), p. 367. $R = \frac{d}{(n^2-1)/3}$ which gives a perfect score of 1; the score of a correctly placed letter in a series of $10 = 0.1$.

(9) *Memory of Consonants*

The consonants were printed by hand in capitals (12-14 mm. in height, strokes 5 mm. in breadth) and were clearly seen from the station of the reagent 5m. distant. The light entered the room through northern windows behind and above the reagents, and the Jastrow tachistoscope[54] was surrounded by black screens which concealed the experimenter and his manipulation of the apparatus. The test was composed of 5 series of 10 letters.[55] The letters were presented at the rate of one second, the series at the rate of two minutes.

Spearman's "Foot-rule" was used for scoring.

(10) *Memory of Numerals*

The procedure was the same as above except that digits[56] were presented instead of consonants.

(11) *Memory of Visual Signs*

Procedure was the same as in No. 9 except that meaningless optical signs[57] (suggested by and similar to those illustrated by Stratton)[58] were used instead of consonants, and the test consisted of a single series. The reagent reproduced by drawing.

(12) *Memory of Associated Pairs*

The letters of No. 9 and the digits of No. 10 were presented in pairs[59] at the rate of a pair a second, with the Jastrow tachistoscope; after an interval of 60 seconds the series of letters was shown at the rate of a letter in three seconds during which time the reagent was required to record the digit associated with the letter. The five series were separated by intervals of 2.5 minutes. The reagents were especially instructed to depend upon association alone for reproduction.

The scoring was made on the basis of 0.1 points for each correctly recorded digit.

Tests No. 8 to No. 12 were usually given in two sittings.

[54] Illustrated in Whipple's Manual (1st ed.), p. 365.
[55] Appendix B, Fig. 10a (p. 290).
[56] Appendix B, Fig. 10b (p. 290).
[57] Appendix B, Fig. 11 (p. 291).
[58] Stratton: Experimental psychology and its bearing upon culture, p. 29.
[59] Appendix B, Fig. 10c (p. 290).

(13-14) *Learning 12-Consonant-Rectangles*

Through a tachistoscope of the Wundtian type[60] rectangular cards (10.2 x 15.3 cm.) bearing three horizontal rows of 4 consonants were exposed. The letters were printed in black ink with rubber type (21 mm. high), broad Roman rather than Gothic in style[61] (lightest strokes were 1.5 mm.; broadest 4 mm. in width). The disposition of the reagents and apparatus, the condition of the light, etc., were the same as in the preceding memory tests. The letters were clear and distinct from the reagent's position. The time of the exposure was 10 seconds. It was preceded by a pre-signal, "Get ready for No.—," given 7 seconds, and a signal "ready" given 2 seconds before the screen was removed; it was succeeded by a free interval of 10 seconds which was terminated by the signal "Now," when the reagents recorded in ruled forms. The test consisted of 10 experiments, which came at the rate of 2.5 minutes. Introspections were written between experiments and after the test.

In the test with distraction, the reagents were required to add eight digits called out by the experimenter at the rate of one a second, during the 10″ interval after the exposure, and to record the sum before beginning to record the letters.

Records were scored according to the following values for a reproduced letter: 2 points for the correct line, 1 point for the correct column, making 3 points for a correctly placed letter.[62]

Tests No. 13, and 14 were given in a single sitting.

(15) *Word-Completion*

The reagent was furnished ruled paper, and a blotter to use as a screen. Then three separate columns of 10 consonants[63]

[60] Illustrated in Wundt: Grundzüge der physiologischen Psychologie (5te Auf.) 1902, Bd. III., S. 334.

[61] Appendix B, Fig. 12, (p. 291).

[62] Although this method is not satisfactory, and Cohn (*op. cit.* S. 161ff.) and Segal (*op. cit.* S. 136) justly claim that errors demand separate treatment, if a single score is to be derived for a measure of reproduction, some arbitrary method must be accepted and this one combines favorable features in the methods of Winch (Br. Jr. Psych., 1:129) and Smith (Mind, N.S. 5:52). See Appendix C, (p. 295).

[63] Appendix B, Fig. 13, (p. 291).

each were dictated to him which he recorded and covered with his screen, leaving a space of about 4 cm. between the columns. He was then told that under his screen were ten lines of three letters each, and that upon signal he was required to remove his screen and to fill in letters anywhere in order to complete a word on each line. Time was taken with a stop-watch. In case the ten words were not completed within 5 minutes, the unfinished work was taken.

(16) *Trains of Ideas*

Reagents were instructed to begin immediately from the stimulus-word and write by word or phrase as many ideas as possible within the two minutes allowed them. Three stimulus words were given: *horse, potato, flute.* Connections were then explained and the ideas counted.

Tests No. 15, and 16 were usually given in the same sitting with No. 2 and 3.

(17-18) *Extensive Threshold of Visual Attention*

The same apparatus and like material and procedure as in No. 13 were used except the exposure was about 0.1 seconds (0.085″), the free interval between exposure and reproduction was 5 seconds, and the rate of experiments was two minutes. The whole card fell within the angle of acute vision.

In the test with distraction the 5″ interval after the presentation of the card was used by the reagent for adding 4 digits pronounced at the rate of one a second. The sum was recorded before the letters.

Tests 17 and 18 were taken within the hour.

(19) *Tapping*

The reagent tapped five series of 30″ each, with intervening rests of 2.5 minutes. He used his right hand in a manner chosen after a preliminary practice; he was instructed to keep his method constant and to tap as rapidly as possible. The Morse key was sent at a tension of 50 grams, and an amplitude (at the button) of 1 mm. (approximately the adjustment preferred by telegraph operators). Records of the tapping were

taken on a kymograph beside a seconds-line furnished by the laboratory clock.

The kymograph records were scored from the time-line and the taps counted for every interval of 5 seconds. Total efficiency was found by the average of the taps per series of 30 seconds; the "Fatigue Index" was derived by dividing the average of the last five intervals of the first series by the number of taps in the first interval. All procedure was according to Wells[64] except in the use of the right hand only.

d. The Training Results

According to the design of our investigation our chief concern is with analyses of processes, their changes during training, and the factors responsible for improvement. The amount of improvement in training, the probability of the attainment of maximal efficiency, what general conditions correlate with poor and good daily averages, and what special causes of variability affected the scores, are also noticed.

(1) *Extensive Threshold of Visual Attention*

These tachistoscopic practices consisted of 25 1/10-second exposures per day of cards (4" x 6") bearing 12 capital consonants (21 mm. high) (See Appendix B. Fig. 12, p. 291) printed with rubber stamps evenly in three rows. Reagents sat 5 m. distant; experimenter was concealed behind the apparatus which was screened in black. The record of the reagent was made in a ruled form and was begun five seconds after the exposure was made; in scoring, a letter was evaluated three points if correctly placed, two points if misplaced in the line, one point if it appeared anywhere else. Experiments took place at the rate of 1 1/2 minutes. Introspections followed each experiment.

Three reagents, Mn., Le., and Al., took the training, the first two upon three days of the week, the latter upon successive days, at the same hour of the day, and under as nearly constant

[64] Wells: Normal performance in the tapping test. Am. Jr. Psych., 1908, 19:437ff.

conditions as possible. The extent of the training was respectively 18, 18, and 8, days; and the gain over the first day's average was respectively, 29%, 26%, and 29%.

The practice-curves indicate that maximal efficiency had probably not been reached (*vid.* Appendix B. Fig. 14, p. 291).

The day's work was not long enough to produce fatigue. Days of poor scores were days of poor control of attention, of discouragement, of thinking that maximum efficiency had been attained, of being bored by the experiment. Days of good scores were days of good attention, and the best days usually came after a week-end or a short vacation.

The process varies considerably, even during a sitting, and, although many of the factors of variability will be found in the following descriptions of changes in processes during training, some of them may be noticed here.

The degree of attention may vary from 'slack' to "wide-eyed and breathless" (Al.). The presentation may occur just before, at, or just after, the crest of the rhythm of attention. The extent of attention may be confined to a few letters, when they will be clear and the rest of the card may not be seen at all (Mn. 2:24); or it may cover the whole card in which case all imagery may be so vague as to effect a blank score, (Mn. 2:13). In the intermediate cases the attitude toward the more vague content determines whether the interval after perception is given to rote repetition of the 'clear' letters or is given in part to 'maturing' vague letters. Variability arises in the effort to coördinate the latter two processes.

The material for any reagent is not uniform: Some letters, such as form familiar initials or abbreviations, are 'significant' and may challenge apperceptive elaboration at the sacrifice of further perception, (Mn. 6:11); or they may prove more facile in apprehension and more ready for recall, (Le. 15:16). Some letters are more difficult to name (Le. 2:16, 11:8) and some groups are particularly non-euphonious (Mn. 3:7).

Among other subtle causes of variation may be mentioned an inducted effect through rapport between the experimenter and reagent, of the experimenter's variable state of alertness.

During Mn.'s 11th and Le.'s 12th day the experimenter intentionally varied the manner in which he gave the two signals ("Ready for No.—," given seven seconds before, and "Ready," given two seconds before each exposure) according to three types, (a) sharp, alert, (b) indifferent, (c) low, decisive. The averages of both reagents were lowest for the 'indifferent' type; Mn. averaged highest for the 'sharp,' and Le. for the 'low, decisive' type. The experimenter chose the last type and was thereafter careful to keep his own condition of attention more constant.

Since introspections, under the limitation of time, could not be complete, and the respective reagents differed in their selection of factors, the manner in which processes changed through the training will be noted for each of the three reagents separately.

Mn., during the habituation period of the first few days, changed from visual to a kinaesthetic retention because of the higher reproductive value of the latter. Only letters repeated by name were readily reproducible, and the period of exposure or the entertainment of the after-image was so brief as to limit naming to but a few letters: "I seemed to have the time in this case to repeat the (4) letters. I can remember the letters more readily by this process, but usually the time does not seem long enough for this" (1st day, 3d experiment).

At the beginning, when scores were relatively low, attention was usually confined to the first line, or to a part of it, often leaving all the rest of the card unnoticed: ("All the (4) letters were clear, but I didn't seem to see the rest of the card," (2:24)). At this time a whole line produced a good score, but when the score was to become larger, the extent of the attention had to be increased, and consequently its direction changed. This change was facilitated by occasional good scores from relatively indistinct impressions resulting from chance failure to direct attention (1:10); but a too diffuse attention was checked by an occasional blank score due to the imagery being too vague: "Attention on the whole card—can't recall a letter," (2:13). Attention by the 7th day came to be directed upon some other

than the top line (7:3), and by the 12th day, since it was found that scattered letters appeared most frequently above those in clearest vision, the lower part of the card was chosen, the 3d line being favored: "Find I cannot do well at the middle line," (12:16). But these conscious changes in method correspond to 'rests' in the practice-curve, and were not for any length of time strictly adhered to.

Not only did the spread of attention now include letters that at first could not be seen, but visual imagery was required to reproduce the additional letters, since the interval was taken up by the verbal repetition (13:7, 15:3). This coördination of the two kinds of imagery holding their respective content was not at first very good and never did become efficient; the letters held in the visual imagery were prone to escape before they could be recorded (3, 7:17, 15:5) although they sometimes returned (5:14).

Associations of letters with familiar abbreviations, initials, names, words, etc. were not much used. Introspection notes no more than one case (2 or 3 letters) on each of the following days: 2, 6, 12, 13, 14, 15, 16. But the last two days they promised to become prominent; on the 17th 11 letters were reproduced from them, and on the 18th 15 letters. During these days they merely supplanted verbal repetition of letter-names and did not contribute to the larger scores. But had training continued, they probably would have been coördinated with the verbal and visual imagery to the end of fixing more of the impression before it got away.

The attitude toward the vague impressions changed and undoubtedly contributed toward the rise in the curve. It was not until the second day that the five-second free interval before recording was used in part for developing or defining impressions; it was customarily used in merely repeating the names of the letters that had been clearly seen. On the 3d day vague imagery began to yield letters: "The first two letters were very distinct, but I do not know how I saw the last ones: When I was recording them, I felt them rather than had an image," (3:1); "During the interval I tried to recall the letters; and

those recorded are the letters that came, although I have no visual image to prove that they are correct" (3:6). But on the 5th day uncertified material was accepted with caution: "J (a clear letter) always seems associated with L for some reason, and the L forced itself [properly] into the record" (5:20). By the 9th day, however, this material was regularly given a chance, which was almost always warranted by the score. The following will show the character of the material:

7:8 "The impression of the three letters seemed very indistinct, but during the interval they seemed to take a definite form."

8:6 "P was particularly clear; I do not know how I got S for I cannot remember seeing it especially."

9:18 "I remember only seeing V, but during the interval the rest of the line (3 letters) was completed."

10:6 "When I repeated the letters, K and Z were the only decided ones; but during the interval the others seemed to fall into place (2 letters)."

11:4 "L and T were the only letters that were distinct. The others seemed to fall into place during the interval."

12:8 "I do not think I saw the last two letters, but in some way they came to my mind during the interval while I was repeating the others."

14:10 "I did not see the D as the third letter, but something put it there during the interval."

15:3 "I am not sure what the third letter was. When I repeated them I could get no sound in the third space; but visually it seemed to be F, although it does not seem to fit when I repeat them." (The first, second and fourth letters were clear. The third is often omitted by this reagent, and indeed also by others.)

16:5 "I had no idea of the third letter. K came when I repeated them, so I recorded it." (Correct).

16:11 "C came as a feeling; seemed to see a rounded form." (Correct).

17:8 "I got a vague idea of a number of letters, but R was the only clear one:" 4 others were correctly recalled and a P recorded in error for a B.

That this material was related to vague visual impression was indicated by an occasional error: "C and N came during the interval; N was especially insistent," (14:24). (Wrong—the two letters were G and V; similar forms).

There is a fairly good correspondence between a favorable attitude toward the indefinite impressions and the rise in the curve. Improvement was largely due to the development of vague unrecognized material into correctly recorded letters.[65] While this development was in progress there were some tendencies working against good scores: Lines distinctly seen sometimes failed to mature into letters, (8:25), and sometimes letters plainly seen failed to be named and could not be recalled (7:17).

Certain peculiarities of the individual consciousness or of the process had some effect upon the scores: Among them are: (a) the unfavorable effect of favorite or significant letters (M, X, C, Q,) (6:11, 7:9, 10:20, 4:6), through narrowing conscious-

[65] The "maturing" of a latent or subliminal impression, in tachistoscopic experimentation, has been observed by others:

The distinction between the "recalled" and the "means" of recalling, insisted upon by Cohn (Beiträge zur Kenntniss der individuellen Verschiedenheiten des Gedächtnisses. Dritter Internationaller Kongress für Psychologie, in München, 1896:456-458), involves a maturing of imagery; he says that the retained letter may be a visual image while the means to its recollection is an involuntary image in an abstract connection (p. 457), and that when it is schematic, or incomplete, it often "matures" (ergänzt sich) through reflection.

Hylan (The distribution of attention. Psych. Rev. 1903, 10:398) found that "a special effort to recognize an indistinct character would frequently cause it to mature into complete recognition before others which were at first more distinct," and that sometimes the indistinct letter would "come floating into the mind as an afterthought when all had been given that could at first be remembered." The impression of letters exposed serially (rapidly) could be held an appreciable length of time without recognizing a single letter, until each was recognized one at a time.

Bergström (Effect of changes in the time variables in memorizing, together with some discussion of the technique of memory experimentation. Am. Jr. Psych. 1907, 18:236) found that the rapid displacement of one impression by the next interferes greatly with the memorizing, and inferred that an unconscious organizing process (apperceiving or fixing) continues some time after the impression has been received, which is necessary for its permanence and revivability.

ness to them alone; (b) the persistence of impressions from former experiments; (c) the difficulty of cognizing letters of similar form, or of naming and of reproducing non-euphonious groups of letters, (3:7); and (d) the shifting of letters to fill a space occupied by an unseen intermediate (usually the third) letter. The last was largely corrected during the training through increased power to develop letters from obscure imagery.

The facts that the coördination of the two kinds of imagery (visual and kinaesthetic) was not yet perfected; that the coördination of associations with the imagery was just on the point of beginning; and that the coördination of the reproducing and the recording processes was still defective, supports the objective indication of the practice-curve that training had not yet reached maximum efficiency.

Le. changed direction of attention from the first line, when increasing score demanded more than four letters, to the middle line (7th day), and then to the blank space just above the middle line (13th day). These changes were made on the basis of the adequacy of chance variations from the usual method. Extent of attention changed from the first two letters of the first line to four; then this tendency to limit the range to clear impressions changed to include impressions of various lower grades of clearness. Intensity of attention varied from day to day and from experiment to experiment, but effort was made to keep it at maximum: "Find that fair (as distinguished from good) attention makes considerable difference; I see the card as well, but the letters are less clear, and fewer are noted"; and good scores are correlated with introspective report of good attention.

Although extent and intensity of attention, or distribution and clearness, are supposed to vary inversely, there was during the training a development of the field of maximal clearness as well as the lower levels of clearness; and there was a gradual transition from a one-level to at least a clearly eight-level or multi-level clearness of tachistoscopic impressions; the table below, which is made from introspective data, will illustrate:

Table showing eight-level clearness

The figures in the table represent the number of letters reproduced from a single exposure. The figures in the first line stand for the following headings:

1. Day and Experiment
2. Very clear
3. Clear
4. Fair
5. A little vague
6. Vague
7. Strongly suggested
8. Suggested
9. Unrecognized content

1	2	3	4	5	6	7	8	9
1:3		2						
1:5	1	2						
3:12		2	1					
14:2		1	3				1	
14:5		2	1		1			
14:16					6			
14:24	2				2		1	
15:2			5		1			
16:2		5					1	
16:3		3			1		1	
16:21	2				2		1	
17:2		4		1			1	
18:9	1	2					2	
18:11		5			1			
18:13		3			2	1		

In this selection of introspections it is seen that each consecutive level is distinguished from one or more other levels in some individual experiment.

The fringe material gives rise to imagery all the way from (a) no recognition to (b) visual recall, recognition, and reproduction of letters in their proper places; that is, apart from gradual extension of some degree of clearness into its field, there is on the van of this conquest an occasional 'maturing' of its material into correctly recorded letters:

"Had idea of other lines but not enough for recognition."

"Had strong idea of other lines but not enough for recognition."

"Had idea of other letters but could not recall."

"Saw lines but couldn't recognize letters."

"Saw whole line and noted others as containing letters—in past experiments when one line was seen nothing of other lines was noted."

"Other lines noted, a little vague to recall."

"Other letters noticed, almost recognized."

"Saw no letter clearly; all suggested by lines and made defi-

nite by repeating during the interval; not sure of any." (Good score).

"Saw lines, later recognized K."

"Partly seen and later recognized as S."

"In interval named letters in line but did not decide that I had seen R (a fifth letter) until after recording line; then had vague visual image of R." "Added C after writing line, from image."

"Image not determined until after line was recorded."

Again, the suggestion may be definite without recognizing any material as imaged; "No image, letter came with feeling of familiarity."

The way in which the boundary of clearness is extended into the territory of the unrecognizable, may be illustrated by the advance beyond the capacity of the eleventh day to apprehend clearly the four letters in the line fixated:

"Idea of other lines, but not enough for recognition."
"Stronger idea of other lines; not enough for recognition."
"Line clear, extra letter a little vague."
"Line clear, extra letter clear."
"Line clear, two extra letters vague."
"Line clear, two extra letters clear."

At first the extra letter comes as a maturing visual image, vaguely, then more clearly; then it is clear enough to be named and fixed kinaesthetically with the others.

In the very first experiments Le. held her visual image during the 5-second interval after which she named and recorded the letters. Then she named the letters during the exposure, retaining by repetition and recording from kinaesthetic imagery, occasionally receiving an extra letter from visual imagery later. But by the 6th day she gave up the moment of exposure to the vivid life of the after-image, to "Einprägung," and named the letters in the interval afterward; "Named from image one by one as would from card, but slowly." She customarily recorded from kinaesthetic imagery. During this "Einprägung" she 'felt' clear letters in her mouth, the vague letters, suggested by lines, being named for recognition afterward. If letters were not so clear, or formed non-euphonious groups the names were

repeated two or three times during the interval. The visual image of an outlying letter sometimes escaped during the process of naming the others; and when the letter was recalled more vividly for retention during the naming of the others the latter became doubtful owing to faulty coördination of the two processes.

Certain peculiarities of the reagent's process affected the score: (1) She often, especially in dull mental condition, found it difficult to name the letters (2: 11, 13, 14, 15); sometimes she was balked for several seconds (4:15, 5:11, 8:7); and sometimes she would make the best of the situation by miscalling: "Called Q 'H', holding a (corrective) visual image of Q," (4: 19). This difficulty was more prone to occur when Q, Y, or Z began the line fixated (11:8). An effect of the difficulty in naming was to confuse the order (5:8), in which case the letters were named in trial orders until the reagent was satisfied by a feeling of familiarity (4: 11).

(2) Certain combinations of letters flashed into significant groups which at first challenged attention to the exclusion of further perception, but later served readier apprehension; such were the initials of friends, silver-ware marks, etc.: J B, J D, T M, S K, L K, T B (Tuberculosis), S F (San Francisco), etc. W M were noticed to be similar in construction.

(3) All through the training there was occasional self-consciousness in fixating (11: 18) resulting in (a) more or less irregular phenomena, such as winking, shifting, or squinting the eyes, just at the moment of exposure, and (b) eye fatigue and strain (11: 19, 14: 17).

Al. used an essentially different method from the others; he endeavored to get the whole presentation, inhibiting the tendency to limit the area of attention to a smaller and clearer field.

From the 'fringe' levels, letters appeared often through kinaesthetic-auditory imagery and were correctly recorded although they were not remembered as seen; they often matured in visual imagery, generally with doubtful position; and often

letters insinuated themselves correctly into the record because they "seem to belong there," neither 'cue' nor verifying imagery being accessible to consciousness. Perhaps the general method of attending intensely to the whole card favored 'fringe' phenomena.

The fixing of letters during exposure, or while the after-image persisted, was effected by naming the letters; and kinaesthetic imagery was the customary 'cue' for reproducing and recording; sometimes the imagery was supported by visual imagery, and sometimes additional letters were visually reproduced and converted into kinaesthetic before recording.

Sometimes a "curious rivalry" between the two kinds of imagery occurred with respect to what letter belonged to a certain position, in which case records customarily followed the stronger kinaesthetic-auditory. But in some cases the position was medial between the two letters. Again, a kinaesthetic-auditory C was corrected visually to Z. Certain assimilative effects evidently resulted from the rivalry of the imagery: J seems G when the latter was just diagonally below it. Again, this assimilative effect may involve only visual factors: M seems X when the latter was just above it.

Mnemonics were avoided and very few associations involuntarily occurred.

Development consisted in more adequate control of the attention during (a) apprehension, (b) fixing, and (c) reproducing periods. (a) On the second day the reagent recorded, "Have learned to regard the card as a whole; distinguish many more letters than at first, but cannot fix them;" and of the letters distinctly seen, three introspections of the second, third, and sixth day's record: "Saw more letters distinctly than ever before," "Saw more letters, say six," "Saw more letters, say eight or nine." Particularly for the earlier part of the training, apprehension in its advance far out-distanced fixing and reproduction. (b) More visual images were named and fixed, and (c) in reproduction the reagent ceased to distrust insistent, but not perceived, letters, as persisting from some former apprehension, and became willing to give them a chance in the score.

Many letters, no doubt, through this change of attitude toward the 'fringe,' 'matured,' as is indicated above in connection with attention; at any rate the scores generally justified the record.

Further and more direct evidence of the more efficient control of the attention, noticeable through lack of strain, is given in an introspection on the 7th day: "Attention as usual, 'open-eyed,' to take in whole card, but not breathless as formerly."

Al.'s maximum daily average occurred on the 3d day (see Curve, Appendix B. Fig. 14, p. 291), and the question arises as to whether all the improvement of his training was made during the first three days of work, and therefore likely to lie in an habituation which lacks the general character requisite for transference. If there was further improvement it was such as failed to affect the scores. Were the same question to be put concerning Mn.'s training for the same length of time (8 days) the same hypothetical conclusion would result, for the first daily average to exceed her third was the ninth. Yet in the face of the gradual ascent of her practice curve up to the 18th day, the probability of improvement on the days between the 3d and the 9th can scarcely be denied.

In what then would Al.'s improvement beyond the 3d day consist?

Tabulation of letters recorded as doubtful indicates that the averages of the days following the 3d were made up more largely of 'fringe' letters and less clear letters; if we express in per cent of the average scores the amount contributed by 'fringe' letters during the course of training, we get: for the 1st and 2d days, 8%; 3d and 4th days, 4.4%; 5th and 6th days, 20%; 7th and 8th days, 17%.

The averages from which we have inferred corresponding capacity therefore represent, in part, disparate processes. And since the conquest of the 'fringe' content in consciousness was seen to be an essential part of progress in the cases of Mn. and Le. and since it has been taking place with Al. since the 3d day, it seems more than probable that improvement has continued throughout the training. This view is strengthened by the introspective notes clearly indicating increase of sensitivity,

and by the experience, common to all reagents, of confusion in reproduction of the distinct content through effort to mature further 'fringe' content. Advance has been made in apprehension; training had not continued long enough to coördinate the part-processes sufficiently for reproduction to show the gain.

For all of the reagents the effect of training was in the following points the same: (For Al., omit a, d, f, h):

(a) More letters were clearly seen,
(b) More letters were distinctly seen in less clear imagery,
(c) More 'fringe' material developed into letters,
(d) There was more efficient coöperation of kinaesthetic and visual imagery for the purpose of recall,
(e) There was less variability of attention,
(f) There was more adequate distribution of the attention to the part-elements of the process,
(g) There was greater ease, less strain, in perception, retention and reproduction,
(h) There was more apperceptive and associative process in apprehension of letters, serving a fuller content and surer recall.

(2) *Learning 12-letter-Rectangles*

Rt. and Sl. gained upon their first day's average 53% and 42%, respectively, during their 18 days of training. Maximal efficiency had not yet been reached (see practice curves, Appendix B. Fig. 15, p. 292). The daily work was not sufficient to show the influence of fatigue.

Days of low scores were: after Easter vacation, when efficient coördination of part-processes had to be built up again, for there was a reversion to earlier processes; and days of poor attention.

Rt. began learning regularly with the first line and proceeded as in reading. He got a strong visual impression and converted it into kinaesthetic-auditory imagery for retention and reproduction, repeating it during the 10-second interval. Upon the first day he began to convert the stimulus immediately into kinaesthetic-auditory imagery without reinforcing the visual impression, and when visual imagery of letters revived after they were retained and reproduced by the Kin.-aud. imagery, it was deemed

a hindrance. In case some letters were held visually after the screen had fallen they too were named and included in the repetition of kinaesthetic-auditory imagery. But when such a visually held letter was remote, in the third line, it was retained visually while repeating the other letters in kinaesthetic-auditory imagery (which by the end of the first day decreased in its auditory support) and was converted only upon recording. Up to near the end of the 2d day the few associations that occurred were also deemed a hindrance, for the letters were, like the earlier visual letters, retained kinaesthetically: "Associations annoy me." But in a few experiments an association came in a convenient place, after six kinaesthetically retained letters, and its letters were not repeated during the interval but were recorded from the visually held association. This is, in brief, the way in which visual imagery in direct form, and association, grew into value as supplementary devices to the kinaesthetic rote method of learning, the coördination of which played so great a rôle in raising scores as training proceeded.

The first appearance of the developed method was on the 2d day (16th experiment) when the first six letters were held kinaesthetically, the next two by associations (CP, chemically pure), and the next two visually; only the first six letters being repeated by rote during the 10-second interval before recording. In the first experiment of the 4th day this method recurred, the association being LB (pound). But it took the training of the 4th, 5th, and 6th days to make this the predominant method, which with favorable modifications gained in elasticity and value until the maximum scores were made.

During the period of emergence of this method, of the three-fold content, a two-fold content was dominant (see Analysis Curves, Appendix B. Fig. 16, p. 292). After the third day it was a rare score that contained only kinaesthetically held letters, although 12 out of the 3d day's 20 were such. The independent visual images of letters were held side by side with the kinaesthetic, except that the kinaesthetic were being constantly repeated during the free interval, while the visual persisted from the first reinforced impression. During this

development of the coördination of the two processes of retention and recall, a secondary visual imagery emerged, weaker than the other and often accompanied by doubt as to its value. It was imagery persisting apparently in its own strength, not having been reinforced during perception; and it often came late,—after all other letters had been recorded.

It was this last kind of visual imagery, strengthened and made more reproducible through training, which later became available when associations could not be readily formed, to prevent the learning process from lapsing into the early two-fold form. Under favorable conditions six letters were as many as could be safely held kinaesthetically, and four visually (primary), which would give a score of 30 points, and some of the daily scores exceeded this. Since coördination of the three-fold process involving associations, which became dominant on the 7th day, had resulted in carrying out the two-fold process, in experiments in which associations were not found, before the interval of exposure closed, time for strengthening the secondary visual imagery was provided.

In successful work therefore, the process became at least three-fold. On the 10th day a four-fold process appeared several times, (letters held in kinaesthetic imagery, visual associations, primary reinforced visual imagery, and secondary visual imagery).

The general method became elastic in recognizing favorable associations in other positions than in the two spaces following the 6th, to which they had heretofore been confined; i.e., the six letters to be learned by rote changed from the first six to any not available for associations. Three times on the 16th day associations fixed the first two letters, and through the later period of practice all spaces presented favorable associations.

The character of the associations seems to be largely visual; the stimulus yielding a word in visual form. It seems doubtful if many are accompanied by meaning, or at least if the meaning is prominent as it would be if the associations were apperceptive; the reagent calls them "visual" associations throughout.

Letters held in each kind of imagery sometimes escaped, and occasionally returned later in time for recording.

The method of recording passed through a development. At first it followed the order of the letters on the card. Later, the visual imagery, which under low conditions of attention faded rapidly, was recorded first, then the kinaesthetic, then associations, and last the secondary visual. The order of recording followed the increasing reproductivity of the material, except for the secondary visual imagery.

Some variable influences upon the score were apparent:

(1) If attention was not good,
  (a) Naming for kinaesthetic images was retarded,
  (b) Visual imagery was weak, and
  (c) Possible associations escaped notice;
  (d) All imagery, especially visual, faded rapidly, and sometimes escaped during the interval.
  (e) In recording, some of the imagery escaped, and the order of the letters recorded was confused.

(2) Some material was harder than others to pronounce and retarded the process.

(3) Unusual associations, especially at first, retarded the process.

(4) Since forming associations became a prominent motive in the method, material difficult to associate decreased, and material furnishing easy associations increased the score.

Improvement seems to consist in
  (a) Higher sensitivity for the visual material, since the secondary visual images developed, and moreover, into two grades of clearness.
  (b) Higher reproductivity of letter-names.
  (c) Coördinating kinaesthetic and visual processes, so as to develop from a two-fold to a four-fold content.
  (d) Greater facility in forming visual associations.
  (e) Greater facility in apportioning the letters on the card to the appropriate part-processes.
  (f) Better coördination of the recording process with the retaining process.
  (g) Better method in recording with respect to the vividness of part-contents.

(h) Possibly an increase in liability of reproduction of all imagery.
(i) Decrease in variability.

Sl. began learning by repeating the letters on the card in reading order. Upon the first day he attempted to visualize the lower row, middle row, or the top row, while he repeated by rote the other two rows which he intended to hold kinaesthetically; occasionally he sought by tense staring while naming to have visual imagery support the kinaesthetic. In the 15th experiment of that day he hit upon an association: BRQM (Laxative Bromo Quinine) and recorded LBRQ, and noted in his introspections that "It probably did not help me to remember."

The next day he tried to fix all the letters by naming, and found it too much, losing, in that experiment, all but one line. He then began his later method by confining his rote memorizing (Kinaesthetic) to the eight letters of the first two lines and held as much as possible of the third in visual imagery. In a few cases the kinaesthetic imagery of the first two lines was supported by associations: JPN (Japan) and BHSR (Belshazzar); and again WMBR (Wamba).

Upon the 3d day his visual imagery of the third row was assisted by associations (Z, last letter of the alphabet, and J his initial). Thus appeared the alternate form of his method. But it was not yet a conscious method, and was not much used until the 9th day from which time it was used to fix about as many letters in the third line as were reproduced visually. "Can repeat only names of first two rows so as to remember them; either have mnemonic for third row or visualize." A curious thing appears to have occurred during its emergence at that time, which seems rather an effect than a cause of its use. The visual imagery used during the preceding four days seemed to change to what was called in the discussion of Rt.'s results a 'secondary' form (*i.e.*, not reinforced during perception) or an apperceptive form involving alphabetic position, which related it to a class of the associations available and used at first

particularly for X and Z, as is shown by the prevalence of substitutions of near-lying letters, as H for J or K. The reagent repeatedly said he did not visualize, neither did he repeat, nor did he form those letters into associations—he "just remembered them." "Last letters written in lower row are remembered by gazing steadily at them and names are not pronounced neither are they visualized." He also records some letters from this field which he cannot account for: these are what I have called the 'secondary' visual form, when they came in the visual mode. Apparently one cause for this change in the character of his visual imagery is that as he gazes at them he is not so much intent upon sharp visualization as upon seeking mnemonic devices to fix them.

Up to this time he had made three perfect scores by holding the lower row in visual imagery. From now on, all his perfect scores (22) with one exception were assisted by associations, the first three occurring on the 9th day.

The following table shows the relative use of his three kinds of retention for the third row, the 'visualized' and the 'secondary' visual letters combined:

Day	No. of letters recorded from each		
	Kin.	Vis.	Ass'ns
1	4	1	0
2	2	3	1
3		11	2
4		7	8
5	5	22	6
6		10	4
7		28	0
8		18	8
9	9	9	18
10		18	17
11		29	17
12		15	17
13		10	18
14		12	8
15		20	32
16		34	11
17		16	32
18		14	34

By the ninth day his method was to gaze at the 3d row during the exposure seeking a mnemonic association or visualizing while he was repeating by rote the eight letters above held in peripheral vision.

Conflict between the visual and kinaesthetic processes encouraged the search for mnemonic aids. His visual imagery was very unstable and vanished upon slight provocation. If it was to persist, it had to be made as vivid as possible during the impression; but that took attention from the rote process with the result of losing some of the kinaesthetic letters, or of losing the rhythm and sequence, which led to transposed letters in the record; then again, if effort was put disproportionately upon the kinaesthetic process, the lower row would be lost.

The associations were not used advantageously above the 3d line; in fact they were disturbing there. They often resulted in substitutions of other letters, indicating that the form of association was not visual, as in the case of Rt., but more apperceptive. Sometimes they were of a complex nature: MDKS was held by "M.D., Mark Keppel, Snell;" ZGJX, "between special letters ZX, George Jones." Sometimes letters in a well known combination would be absorbed in another more special but earlier one: PBDV gave Peabody, although since the combination had occurred before, "deo volente" had been common for DV.

The visual imagery of letters seemed to be more easily held if they were accompanied by associated letters, and the process was often thus a three-part process: Kinaesthetic for 8 letters, associative for 2, visual for 2.

A peculiarity of Sl.'s imagery was that as long as he held his eyes on the screen, after the exposure, the letters remained there; but as soon as he glanced down to the paper, they either vanished or took a position on his forehead where they were very unstable and were apt to escape while he was recording the kinaesthetic letters. It took special effort to retain them.

His other imagery was also quite unstable, for any inner distraction was fatal to it; upon one occasion he began record-

ing with the wrong letter and almost lost the whole score. He tried to hold the imagery by keeping his body rigidly in the same position. Recording was an especial distraction.

A development of the kinaesthetic process took place: At first he merely named letters "in his mind," then in a whisper, finally with very slight throat and tongue movement. The first was not vivid enough and the second was too slow.

The variable influences upon the score recorded in the discussion of Rt.'s training were present here also; except that No. 3 may be omitted and No. 4 made applicable to the 3d line only.

Improvement seems to consist in

(a) Coördination of visual, kinaesthetic, and associative processes.
(b) Using incipient pronunciation with rote process.
(c) Better apperception of visual images.
(d) Coördinating the recording and retention processes.
(e) Making association a method.
(f) Decrease of variability.

It does not seem that sensitivity to visual imagery, or that reproductivity except as better effected through (b), was increased; and the method remained fairly mechanical.

(3) *Reaction to Sound*

Ly. did not greatly reduce her reaction time by her training of 11 days, 100 reactions per day, (1.4%).

That there was a change in the process is indicated by the character of the practice curve: There was a drop down to the 6th day, showing at that point over initial capacity a gain of 19%; but from then on there was a gradual rise to almost initial efficiency.

If the ten reactions each of the 27 series, on the 100-gram tension of the key, are distributed and plotted (5 sigma to the plot) in three distribution curves of 90 cases each (corresponding curves, with 10 sigma to the plot, are shown in Appendix B., Fig. 18, p. 294), it is seen that the motor reactions with times around 100 sigma have fallen away, after the middle period;

that the highest mode has shifted from 158 in the first period to 178 in the middle and last periods; that the chief block of reactions which came, in the first, between 130 and 170 sigma, has broadened in the middle to 180; and that the last curve is cut by a cleft at the point where the first has the highest mode, giving rise to two blocks: 130-155, 160-195. The median has moved from 159 to 160 and 165.

The introspections throughout are headed "Sensorial"; at the same time, individual introspections note pressures, strains, and tensions in the fingers, hand and arm, and premonitory reactions indicate a motor direction of attention. Although the introspections are not full enough to determine definitely, yet there is some evidence that the process of reaction became less motor as practice continued, after the sixth day. It may be that as training proceeded the sensorial form was more nearly approached, yet the first considerable mode of the first curve, from 130-145, continued and broadened toward longer time, in the middle curve, has split in the last curve with the narrower mode at 130-135 and the broader at 140-155, whereas the former mode of 130-135 would seem to be the place for a practiced sensory time. The widening of this mode in the second curve, and the growth of a wide mode from 140-150 in the last, seem to indicate the development of factors in the process of reaction which (a) shifted most of the 'sensorial' reactions to 140-150, and (b) gave rise to a more frequent type of reaction at 160-195, where the last curve has its largest block of reactions and the first curve is most serrated. Introspections do not make clear what those factors are; but they must be such as cause reactions to fall central upon 148 and 178 sigma.

The process at the beginning of practice was sometimes pure motor (90-110 sigma), often sensori-motor (110-120), very often sensory (130-140), and more often a complicated sensory (145-165). During training, the motor disappeared, the sensori-motor diminished, and the practiced sensory narrowed (130-135), the sensory (135-150) became more frequent, and the

complicated sensory (160-195) most frequent. This development into longer time conforms with Bergemann's results on influence of practice on sensorial time.[66]

There was a decrease in variability, which is usually taken to indicate improvement in attention, but it is still large (MV., 13%), about 5% above practiced form (8% of the mean).

(4) *Memory Training*

He. and Cr. tested mnemonic devices for memory of figures, dates of events, and lists of words.

Although the modern[67] systems of mnemonics have the advantage of the older[68] in that they rely upon the congruence rather than the incongruence of the supplied mnemonic word or phrase, they are open to two chief criticisms: (a) They add to the material to be memorized, and (b) the supplied mnemonic is likely to be replaced by a false one (He. lost the key-word "pass-key" in the mnemonic for Homer, by substituting "latch-key", which changed the date from 907 to 567). The chief advantage of mnemonics appears to lie in the better apperception of the data to be remembered, by reason of subjecting them to especial attention in order to determine that they are correctly represented in the key-word of the mnemonic. Since the *natural* relations in the data are obviously the more profitable to be scrutinized, the advantages outweigh the disadvantages, if anywhere, only in the learning of dates, telephone numbers, street numbers, or other disconnected numbers.

That great advantage is gained by inspecting and grouping numbers, not for the purpose of transposing them into mnemonic phrases, but for noting the relations subsisting between the respective groups, was shown by the correct reproduction of series of 24 digits after grouping them into three's and inspecting them just once.

[66] Wundt: Physiologische Psychologie, III:421, (5te Auf.).

[67] *E.g.*, Harvard College—Teach much—t-ch-m-ch—1636. (*Vid.* James: Briefer Course in Psychology, p. 74; or Prin. of Psychology, vol. I, p. 669).

[68] *E.g.*, Xenophon—a-zang-for-fun might do damage with *matches*—m-tch-s—360.

The principal object of the training, however, lay in the repetition of lists of words, in conformance with Loisette's[69] instructions for the training of attention by "compelling the intellect into some particular channel and keeping it there," "by compelling the intellect to stay with the senses," through analysis of connections between words in a series and frequent rapid repetition with full concentration. He claimed to have made weak memories strong, and good ones better, by this method.

The method involved (a) an attentive apprehension (auditory or visual) of a list of words, having a more or less obvious sequence, with the view of noting the relations between each two words, and (b) an immediate recall of the whole list after the single apprehension. Later, on succeeding days, the lists were to be repeated orally from memory, forwards and backwards, as rapidly as possible, recalling clearly the relations between the words. Notes were taken of the time and errors. The reagents set for themselves three subsidiary aims: (a) to determine the advantage of scrutinizing the relations between the successive words, for reproduction after a single impression, (b) to learn whether the initial stability of the particular connections remains relatively the same in successive reproductions, and (c) to learn if the liability[70] of recall remains the same in successive reproductions, as shown by the time to reproduce the series.

The second list of 30 words began with: Building, dwelling-house, parlor, partridge, feathers, light, lighterman; the relations between the words are: genus and species, species and genus, whole and part, partial identity in sound, whole and part, substance and attribute, partial identity in sound. The list was dictated to He. by Cr. at the rate of one word per second, and was reproduced orally by He. in 160 sec. and by Cr. in 58 sec. Three lists were learned and reproductions were made on nine days after March 3d, to April 14th.

[69] Loisette: Assimilative Memory, 1896, p. 20.

[70] For the special meanings of "liability" of reproduction, and "fidelity" of reproduction, *vid.* Külpe: Outlines of Psychology, p. 197.

The chief subsidiary results may be stated as follows:

(a) Scrutinizing the words for relationships results in successive associations of contiguity reinforced by a unity in meaning: *i.e.,* in the "Pointer, oak, ax, steel, ore, mine," series, Pointer, oak, are not only together in consciousness as two words, but the pointer is visually or kinaesthetically imaged as an oak pointer; and oak, ax, are unified in an image appropriating any suggested relation between them, as of cutting down the oak tree, or of fashioning the pointer; Building, dwelling, house, are imaged as separate buildings in a hamlet, bearing spatial relations to each other, and parlor and partridge are in the dwelling—they all constitute a simple 'complex'. Incentives for recall are thus doubly strong. The reagents were surprised that the process of reproduction after a single impression went off with so much facility and with so few errors.

(b) Although certain parts of a series visualized or imaged in a 'complex', fitted into a story built up through the imagery suggested by the words at the first impression, seemed to be more difficult and to demand more attention, in subsequent reproductions, than other parts, this difficulty resulted in halting the rhythm of repetition rather than in errors. The errors were almost wholly omissions, occurring in almost any part of the series, but seldom recurring in subsequent reproductions. They are caused almost wholly by incentives of recall reaching beyond the next member in the series. Introspection indicates that incentives reach from one 'complex' to another so that the most important member in the next 'complex' comes into consciousess before all the members of the last and the beginning members of the next are recalled, and that this consciousness of direction gives confidence and facilitates repetition. In this way ground is covered from one 'complex' to another by neglecting some of the intervening members. The incentives of recall of the next word constantly vary in successive repetitions. To attain accuracy intense concentration seems necessary, unless the process is to become merely rote-repetition by the vocal organs, which throughout was guarded against under the injunction of the training to "keep the intellect with the senses."

(c) The liability of recall, as shown by the time taken to reproduce the whole series, fluctuates constantly from day to day, yet considerable practice-effect was shown by both reagents, which indicates that in general liability or recall increases under conditions of relatively few repetitions during a long interval of time. If a free interval before a subsequent reproduction is but two days, the liability of recall is considerably increased, as shown by decrease in time; if four or five days, it is still increased, if 14 or 15 days, it is slightly decreased—about as much as it is increased after four or five days.

The advantage of the use of mnemonic connections in learning German-English vocabulary (*e.g.*, mistrauen—miss—shy girl—shy—diffidence) was not definitely determined; although a list of vocabulary could be repeated with certainty after one perusal, that perusal took about as much time as equally efficient direct learning; and although the former has the advantage of the use of the logical memory, while the latter relies more upon sensory memory, its connections seem to drop away with the flight of time about as rapidly as sensory memory falls away.

Concerning the principal object of the training, introspection says: "Takes intense concentration; afterwards feel tense in the frontal regions." But beyond the feeling that attention was keenly experienced in the training, and therefore presumably improved, there is no quantitative evidence at hand to show that improvement was made.

This training was not as regular nor as systematically controlled as the foregoing.

e. The Test Results

In the following discussion of test results we shall notice chiefly (1) the extent of variability in mental processes between different reagents who apply themselves to the same objective task,[71] (2) the extent of variability in a single

[71] Some of this variability will undoubtedly result from differences in 'type,' whatever that proves ultimately to be, but the following discussion takes no account of it; owing to the difficulty of diagnosing and adequately describing an individual's 'mental type,' since all individuals are probably mixed types

reagent's processes while applying himself to the same objective task, and (3) the conditions which must be met for the scores to be comparable. (4) The causes of variability, so far as they appear, and (5) the effect of variability upon the scores, are not neglected.

According to the form into which we have cast our tests and training, it must be remembered, the particular influence of training upon these tests which we are seeking is that of improved attention. The initial efficiencies of the first series of tests constitute a cross-section of the initial capacity of attention; the final series of tests gives the final capacity of attention. If the processes in the final test have changed essentially from those employed in the first test in some other way than may be attributable to better attention, if, for example, the method of work is different, then the difference between the two scores would represent something besides the change in attention, and could not be used. At best, such a difference-score could only indicate the advantage or disadvantage of doing the task in another way. Scores of the same reagent to be comparable must consequently represent similar processes; scores of different reagents to be comparable, we must assume, should also represent similar or at least equivalent processes, and score-differences, or per cent of change in efficiency, to be comparable should be based on something near equal initial efficiency.

When comparable, the difference-scores of the trained and control reagents will be inspected for transference of improved attention.

The degree of analysis in the various tests is not uniform for the reason that the processes engaged in the tests varied

which vary according to means of diagnosis (*vid.* Segal, *op. cit.* and Fernald *op. cit.*), only the following general and perhaps untrustworthy characterization of our reagents, based largely upon questionnaire replies (Wissler: *op. cit.* 8-9) supplemented by oral report, may be offered:

	Mn.	Le.	Rt.	Sl.	Ly.	He.	Cr.	Al.	Ms.	Wf.
Visual	Strong	Strong	Strong	Weak	Strong	Fair	Weak	Fair	Strong	Weak
Auditory	Good	Strong	Weak(?)	Weak	Good	Good	Good	Good	Strong	Weak
Kinaesth.	Good	Strong	Strong	Weak	Good	Good	Good	Good	Strong	Weak

greatly in complexity, and the introspections of the reagents consequently varied correspondingly in completeness; but effort is made to analyze the tests employing the less complex processes fully enough to serve our primary purpose and to contribute to the popular notion of the nature of 'mental tests.'[12] That the extent of variability may be adequately indicated, all the tests are subjected to analysis,—an analysis that is not merely a logical schematism, but an empirical construction built up from the introspections.

(1) *Reaction to Sound*

Simple Reaction Time has been used in the study of Attention (Angell and Moore,[1] Binet[2]), in determining mental and physical correlations with children (Gilbert,[3]) and with university students (Cattell,[3a] Cattell and Farrand,[5] Wissler[4]), in determining psychological norms of men and women (Thompson[6]), and in the study of individual psychology (Binet et Henri,[7] Henri[8]). The latter[8a] emphasize the value of the M.V., which has been suggester by Titchener[9] and Pillsbury[10] as a possible measure of attention, and has been denominated by Buccola "the dynamometer of the attention."[11]

[1] Angell and Moore: Reaction Time: A study in Attention and Habit. Psych. Rev. 1896. 3:245-358.

[2] Binet: Attention et Adaptation. Année Psych. 1899. 6:276ff.

[3] Gilbert: Researches on the mental and physical development of school children. Studies from Yale Psych. Lab. 1894. 2:81.

[3a] Cattell: Mental Tests and Measurements. Mind. 1890. N.S. 15:376.

[4] Wissler: Correlation of mental and physical tests. Psych. Rev. Mon. No. 16. 1901. P. 7.

[5] Cattell and Farrand: Physical and mental measurements of the students of Columbia University. Psych. Rev. 1896. 3:639ff.

[6] Thompson: Psychological Norms in men and women. Univ. Chicago Contrib. to Phil. 1903. 4:8ff.

[7] Binet et Henri: La psychologie individuelle. Année Psych. 1895. 2:445.

[8] Henri: Étude sur le travail psychique et physique. Année Psychol. 1896. 3:245.

[8a] Also, Binet: A propos de la mesure de l'intelligence. Année Psychol. 1905. 11:69-82.

[9] Titchener: Simple Reactions. Mind. 1895. N.S. 4:79; also, Lectures on the elementary psych. of feeling and attention. 1908. P. 280.

[10] Pillsbury: Attention 1908. P. 89.

[11] Buccola: La legge del tempo nei fenomeni del pensiero. Milano. 1883. P. 155; (Quoted by Oehrn: Experimentelle Studien zur Individualpsychologie. Psych. Arbeiten. 1896. 1:113).

[12] In order to allay any suspicion that our tests are not representative and are peculiarly subject to variability in processes, a paragraph, with references, showing the relation they bear to other tests reported in the literature, is added to the discussion of the results of each test.

It is well known that intensity of attention lowers both the time[73] and the relative variation in simple reaction. But for averages to show this, they must not be influenced by other causes of variability: Health, 'Anlage,' habituation to external distraction, and the direction of the attention must remain uniform. The introspections indicate extraneous causes of variation:

(a) Conditions of health, through good, dull, tired, nervous, etc.
(b) 'Anlage', from interest to indifference, calm to anxious, natural to muscular or sensorial set of consciousness.
(c) Process, as regards habituation to external distraction (such as noise, unaccustomed finger reaction, pressure on the key, temperature of the hands); as regards fluctuation of the attention, within the series, between muscular and sensory reaction.

Another variable factor lies in the movement: In raising the finger, the extensor muscle must overcome the flexor, and owing to the balance between the tensions of these antagonistic muscles, the reaction movement is not simple but varies from a simple extensor reaction retarded by flexor tension, to an extensor reaction preceded by antagonistic flexor reaction which delays the reaction movement 40-50 sigma,[74] and three types of this variable factor have been observed.[75]

Examination of the test averages and the distribution curves confirms and supplements the evidence of introspections. Clearly, the test averages cannot be handled recklessly. They cannot be compared at random for at least four good reasons:

(a) The change in the direction of the attention within the series, as shown by a bifurcated distribution curve, and by a large mean variation, is compatible with good attention. The average of such a series might lie above or below that of a series obtained with an equal degree of attention, but where the direction of the attention remained constant: *e.g.,* The attention of Le. may have been quite as good in the series giving an

[73] Cattell: Phil. Stud. 3:329ff.; Pillsbury: Attention, 82; Külpe: Outlines, 432.
[74] Smith, W. G.; Antagonistic Reactions. Mind, 1903, 12:47-58.
[75] Judd, McAllister, and Steele: Mon. Supp. Psych. Rev., No. 29, pp. 141ff.

average of 117.2 with a mean variation of 16.6, as in the series giving 136.4 with a mean variation of 4.6; and it may have been no better.

(b) Even when the direction of the attention is constant and the psychical process is about the same for the individual reagent, his results cannot be compared with those of another reagent whose process, as shown by a widely different average time, is essentially different, for the 'abbreviated' and the 'complete' forms are not merely different forms of the same act but are different acts,[76] and practice-effect is greater upon the 'complete' than upon the 'abbreviated' type.[77]

(c) Test averages which include great practice-effect are not comparable with those which do not, for they are not so reliable a measure of efficiency.

(d) Test averages of reagents showing widely different facility also are not comparable because the reagents cannot be assumed to be doing the same work.

Were all of the variable influences to remain about the same in the final tests as they were in the first, and were the essential processes also to remain the same, for each reagent, then all the averages might be used in determining influence of the training interval. In so far as our results vary from this requirement, they have to be put aside.

Distribution curves show changes in the essential processes in the final test, for the majority of the reagents: Le. from an automatic (95 sigma) and a muscular mode (110-135) to a sensory (140); Sl. from a sensory (145) to an automatic (95) and two muscular modes (130, 115); Ly. from sensory (145-155) to automatic (100-125); Cr. from muscular (111-120) to sensori-motor (130); Ms. from less to more automatic (94-100) and muscular (125-130); Ct. to less automatic (90-105) and to more motor-sensory (144-150).

The reagents differed greatly in initial efficiency (ranging from 116.0 to 186.1), and fall, in that respect, into four groups about the following averages: 115, 130, 155, 185.

[76] Angell and Moore: Reaction Time. Psych. Rev., 1896, 3:245.
[77] Wundt: Physiologische Psychologie, 1903 (5te Auf), 3:419.

The per cents of change in the final test from the first, for the reagents whose scores are fairly comparable, are:

	Trained	1st Control[78]	2d Control
Group 2	Mn. -4.3 PE 4.38	Wf. -0.15 PE 3.40	
	He. 5.8 PE 5.62		
3	Rt. -17.0 PE 6.05		
4			Rr. -6.7 PE 20.

And these figures are not entirely free from other causes of variation besides change in processes: Those of Rt. and Rr. are too great because of the large practice-effect in their first test (Rt. 80 sigma, Rr. 40). The loss of He. resulted from the fact that his first test was taken in practiced form, just after long practice in another experiment. Wf.'s decrease of time should have been more, for at the beginning of his final test he was "rather fatigued," and for the latter part "somewhat nervous," and his first test was taken while still in practiced form from preceding experimentation.

The absolute difference for Mn. is a third larger than the probable error, for Rt. three times as large, for He. a half larger, for Wf. and Rr. much less.

In concluding our comparison we can only consider it possible that Mn. and Rt. have transferred some improvement to this test: Mn. from tachistoscopic training, and Rt. from a slight practice in simple reaction to visual stimuli if not from his training in Learning 12-letter-rectangles.

Nor with the averages for variability are the results more decisive; yet, as was noted above, they are recommended as measures of attention. This would be true, no doubt, if the measure is to include steadiness of direction as well as of intensity of attention, as was suggested by Whipple.[79] Yet, were the direction of the attention constant, it is not obvious that a given amount of variability from a 'sensorial' average is just equivalent to the same amount of variability from a 'muscular'

[78] The 1st Control reagents are those who took all the tests; the 2d Control, those who took but one pair or a few pairs of tests.

[79] Whipple: Reaction Times as a test of Mental Ability. Am. Jr. Psych., 1904, 15:496.

average, even when both averages are made by the same reagent;[80] much less when made by different reagents. On these grounds then, the variation averages of all those who changed in the form of their reaction, in the final test, must be disregarded, which leaves the following:

	Trained		1st Control		2d Control	
	MV	r.v.	MV	r.v.		
Group 2	Mn. -4.7	-5.1	Wf. 2.7	1.9		
	He. 0	-0.9				
Group 3	Rt. -1.7	0.9				
Group 4					Rr. -10.8	-3.8

The r.v. = MV/M x 100,[81] and makes the figures somewhat more comparable than without the reduction.

Variation in initial relative variability ranged from 8.0 to 18.8. The increase of Wf. is due in part to his low variation in the first test, taken when he was in practiced form, and in part to nervousness and exhaustion in the final; the decrease of Mn. and Rr. is principally due to better habituation to experimental conditions, Mn. possibly bringing some advantage from her training with the tachistoscope. Part of Rr.'s great decrease must be attributed to his extreme nervousness in the first test (his first Avg. MV was 45.9, while Mn.'s was 17.5).

It is evident that in the reaction-time experiment the reagent must, as Wundt claims, be "thoroughly practiced in the technique," or "there can be no hope of obtaining reliable results;"[82] and that lack of expertness in introspection makes it difficult to group the processes according to kind, so that they may be measured and their measurements justly compared. It is claimed that some reagents are so incapable of control of the direction of their attention that they cannot be used in the experiment.[83] As to the effect of practice on variability, it has been shown under certain conditions to increase it.[84]

[80] *Vid.* Alechsieff: Phil. Stud., 1900, 16:24.
[81] Titchener: Experimental Psychology, 1905, II, I:182.
[82] Wundt: Vorlesungen, 1911 (5te Auf.), S 312.
[83] Lange: Phil. Stud., 1888, 4:479.
[84] Angell and Moore: Reaction Time, Psych. Rev., 1896, 3:245-258.

(2) *Marking Out Small* a's

The discriminative reaction of "Cancellation" was commended by Pillsbury[1] as probably the best test of the positive type for measuring attention. It has been recommended and used for this purpose in almost all of the important studies in individual psychology (Binet et Henri,[2] Henri,[3] Toulouse,[4] Oehrn,[5] Binet,[6] Sharp,[7] Whitley,[8]); it has been used as a mental test in correlational studies (Cattell and Farrand,[9] Wissler,[10] Brown,[11]), as a means of studying the processes of recognition and discrimination (Bourdon,[12] who originated the test), attention and adaptation (Binet[13]), fatigue (Ritter[14]), habit (Bourdon[15]), distraction and habituation (Vogt[16]), general practice effect upon like or related processes (Thorndike and Woodworth,[17] our own experiment on marking out words, pp. 34ff), practice effect upon individual differences (Wells,[18] Hollingworth[19]); and it is included in Whipple's Manual[20] with tests for "Attention and Perception," where an historical and descriptive account of the test may be found. One letter or character may be crossed out, as the small *a*, (Bourdon,[12] Binet et Henri,[2] Toulouse,[4] Sharp,[7] Whitley[8]) or more than one letter, as *a, e, l, t,* or *a, e, d, r, s,* etc., wherever they occur (Binet[6] [13] Ritter,[14] Bourdon,[15] Vogt,[16] Brown,[11]), or words which contain given letters, as both *e* and *r,* may be crossed out (Thorndike and Woodworth[17] and our own experiment, pp. 34ff). The matter containing the letters to be cancelled may be ordinary printed text or printed mixed words, in a known or in an unknown language, printed pages from printer's "pi," small letters or capitals, pages of spaced or unspaced digits, *etc.*

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[1] Pillsbury: Attention. 1908. Pp. 84ff.
[2] Binet et Henri: La psychologie individuelle. Année Psych. 1895. 2:446.
[3] Henri: Étude sur le Travail psychique et physique. Année Psych. 1896. 3:239.
[4] Toulouse: Enquête medico-psychologique sur les rapports de la supériorité intellectuelle avec la névropathie. (Zola) 1896. P. 226.
[5] Oehrn: Experimentelle studien zur Individualpsychologie. Psych. Arbeiten. 1896. 1:98.
[6] Binet: L'Étude experimentale de l'intelligence. Paris. 1903. Pp. 236ff.
[7] Sharp: Individual psychology: A study in psychological method. Am. Jr. Psych. 1899. 10:356.
[8] Whitley: An empirical study of certain tests for individual differences. Archives of Psychol. 1911. No. 19. 3:114.
[9] Cattell and Farrand: Physical and mental measurements of the students of Columbia University. Psych. Rev. 1896. 3:641.
[10] Wissler: Correlation of mental and physical tests. Psych. Rev. Mon., No. 16. 1901. 3:7.
[11] Brown: Some experimental results in correlation of mental abilities. Br. Jr. Psych. 1910. 3:297.
[12] Bourdon: Observations comparatives sur la reconnaissance, la discrimination, et l'association. Rev. Philos. 1895. 40:167.
[13] Binet: Attention et adaptation. Année Psych. 1899. 6:364.
[14] Ritter: Ermüdungsmessungen. Zeits. f. Psychol. 1900. 24:424.
[15] Bourdon: Recherches sur l'habitude. Année Psychol. 1901. 8:330.

Marking out small *a*'s from lines of English print, 93 mm. long, on a page containing 100 of them (see p. 75), is a fairly simple task, but, as introspections show, may involve quite dissimilar processes:

(a) Movement along the line may be like that in reading, may alternate in direction, may embrace more than one line at a time, may be interfered with or facilitated by following a pencil-point.

(b) The essential process may be (1) a search for the form among all the letters, without a unit of material to search through, or with the word or the line as a unit, (2) a search for the sound-image of the letter by pronouncing the words in inner speech, (3) an incipient pronunciation of all the words with the reliance mainly upon the kinaesthetic image of the sounded letter, (4) a reading of the text and reacting upon the words known to contain *a*.

(c) The main process may not be pure, and may be supplemented by (1) elimination of words and suffixes known not to contain *a*; (2) by activity of attention in peripheral vision so as to command a larger field, leading to inaccuracy in reaching too far forward and to accuracy in catching omitted letters in the lines above.

(d) The process may be retarded by distractions such as (1) difficulty with the pen, (2) appeal of the context, (3) looking back to catch possible omissions, etc.

These various processes may be employed singly, in combination, or in succession by a single reagent in a single test; which is sufficient warning that the averages of such tests may not be used for comparison unless similarity of processes yielding them is assured.[85]

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[16] Vogt: Ueber Ablenkbarkeit und Gewöhnungsfähigkeit. Psych. Arbeiten, 1899-1901. 3:73.

[17] Thorndike and Woodworth: The influence of improvement in one mental function upon the efficiency of other functions. Psych. Rev. 1901. 8:553.

[18] Wells: The relation of practice to individual differences. Am. Jr. Psych. 1912. 23:77.

[19] Hollingworth: Individual differences before, during, and after practice. Psych. Rev. 1914. 21:3.

[20] Whipple: Manual of mental and physical tests. 1910. Test, 26, pp. 254ff.

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[85] Peters (Aufmerksamkeit und Reizschwelle: Versuch zur Messung der Aufmerksamkeitskonzentration. Archiv. f. ges. Psych. 1906. 8:391) thinks

. used the visual cue; Mn., Sl., and An. reacted to *a* by an ory image of the word; Al., Le., He., and Wf., to the word own to contain *a,* supplemented by the visual cue. Methods ged some, or were of mixed type, for all reagents during est. For reagents who differed in kind of performance, the ges are not strictly comparable; and for those whose process ged in its dominant elements, in their final test, the average ence-scores express something more than the effect of the ng or the interval upon this test, and must be disregarded: , in his final test, added to his method of attending to s as units and searching for the visual form, direct reaction e word without search; Cr. changed from the kinaesthetic-ory cue to the visual cue; Ms. from the visual cue, supported kinaesthetic-auditory image, to the word cue; Cl., from ing words known to contain *a,* without notice of context, ading the text; and Ly., from the word unit to reading ext. These changes in method are independent of the in-e of training in sustained attention, and were as often vantageous as advantageous.

tial efficiencies ranged from 113-282 seconds, and fall into oups: 113, 129, 145, 165, 190, 280.

e more comparable scores yield the following per cent of vement (decrease in time of 100 reactions) in the final test:

	Trained	1st Control	2d Control
Group 1	He. 9		
Group 3		Wf. 10	
Group 4	Le. 14 Sl. 9		
Group 5	Mn. 29 Al. 15		
Group 6			An. 11.3

eems probable that the practice-effect of the test on itself is 10%; that it was benefited by the tachistoscopic training 10% more, but that it was not benefited by training in on to sound, Learning 12-letter-rectangles, or by Memory

cess so complex that it must be analyzed before any part of it can ected to measurement; for this reason he did not use this test.

Training, or by the other tests in the series. The quick perception of capitals in the tachistoscopic training presumably lowered sensitivity for visual impressions, or shortened cognition-time, which was available for more ready perception of small *a*'s in the text.

(3) *Marking Out Small o's*

Marking out small *o*'s from an *inverted* page of English print containing 100 (see p. 75) of them, was intended to be a process somewhat free from the distraction of the context,[86] which attended the preceding test, and to offer opportunity for a still more simple process, not so capable of change. But introspections proved it to be also quite variable.

(a) (As above).

(b) The essential process may be 1) a search through all the letters for the visual form, without a unit or with the word or the line unit, and with a purely visual image of the *o* or the visual image strongly supported by an auditory or a kinaesthetic image of it; and the kinaesthetic image may be that of a) repeated pronunciation of the name of the letter, b) breathing its sound continuously, or c) pen-movement in tracing its form; 2) a search along the line for the only natural letter, since its form alone is not altered by inverting the page; 3) a blocking of the inverted page into units of a line, or a part of a line, and a 'spotting' of the letter that 'stands out' from its surroundings, (in which case, at moments when the central preparation for its cognition was not perfected by the attention, the *o*

[86] Other methods of avoiding the distraction of the text were noted above; such as, the use of text in unfamiliar language, of unspaced or "pied" material, *etc*. Woodworth and Wells (Association Tests. Psych. Rev. Mon. 1911. v. 13, No. 5, pp. 24ff.), Wells (*op. cit.*), and Hollingworth (*op. cit.*), used digits, which appear to be much the best material yet proposed. The first two researches involved the cancellation of zero's,—a close approach to the present test. Woodworth and Wells (p. 28) note some of the irrelevant individual differences obvious to the experimenter upon examination of the checked page, or upon observation of the performance: variation in the manner of making the cancelling stroke, reversal of direction in inspection of the line, misunderstanding instructions as to amount to be checked over, *etc*.

failed to "stick out in relief from the general blur of letters" and either had to be painstakingly searched for, or its omission risked, either case causing retardation or distraction).

(c) The essential process may be supplemented by: 1) reacting to words recognized as containing *o*, 2) reading inverted words in the search for the auditory or the kinaesthetic image, 3) the elimination, without search, of words or suffixes known not to contain *o*.

(d) The process may be retarded by peculiar distractions: 1) Confusion with inverted *c*, 2) perseverence of tendency to react to *a*'s (this test followed marking out *a*'s),[87] 3) looking back for omissions, 4) tendency to turn the head and eyes to read, 5) recognition of inverted words.

The following reagents changed their processes essentially in the final test: Mn. changed from the visual cue to word-reaction supplemented by looking "for the most natural letter"; Le. changed from one or two words as a unit, to a whole line; He. changed in part to word-reaction; Ms. from inverted image of the word to visual cue and reaction to small words.

Among the other reagents the methods differed somewhat: Wf., Ly., and Al. used the visual cue and reacted to small words; Rt. skipped words and endings known not to contain *o*; Cr. and Sl., and possibly Gl. and An., used the visual cue simply. The more comparable results, because the methods are more nearly equivalent, range in initial efficiency from 125-380 seconds, and fall into four groups: 125, 190, 225, 380. Changes in efficiency are as follows, in per cent of improvement:

	Trained	1st Control	2d Control
Group 1	Cr. 0		
Group 2	Al. 13 Rt. 13 Sl. 3	Wf. 17	
Group 3	Ly. 4		Gl. 4
Group 4			An. 22.4

Disregarding the results of the 2d Control reagent in Group 4, whose initial efficiency was but half that of Group 2, it appears

[87] Binet (Attention et adaptation, *loc. cit.*) found interference in changing from *a, e, d, r, s* to *i, o, l, f, t*, (p. 370).

reasonable to expect about 5% improvement in practice-effect of the test itself; and perhaps 10% more as the result of training on the tachistoscope; none from the other tests or training. Rt.'s gain is largely due to increased facility in recognizing small words and suffixes known not to contain *o* and passing them by; there is no introspective evidence upon which to explain Wf.'s gain, but it is probably due, in part, to change in process. Those reagents who changed processes in the final test show loss more often than gain.

(4) *Card-Sorting*

Card-sorting, a series of reactions with the mental processes of discrimination of the stimulus and the choice of the appropriate movement interpolated between stimulus and reaction, has been used to determine the influence of mental work upon rate of tapping (Dresslar[1]), to learn the conditions of mental activity (Bergström[2]), to investigate the influence of interference of associations upon memory (Bergström[3]) and upon the practice-effect in forming associations (Bergström[4] and Brown [4a]) to determine the effect of mental type on interference of motor habits (McMein and Washburn[5]), to test mental ability (Bagley,[6] Burt[7]), to test motor ability (Thompson[8]), and to study the learning process in relation to transference and interference (Kline and Owens[9]). In the last research ordinary playing cards were sorted into 52 compartments, but usually the stimuli consist of letters (Bergström[2]), nonsense syllables (McMein and Washburn), words (Bergström[4]) pictures (Bergström[4]), or colors (Burt, Thompson, our own experiment on pp. 50ff.); the number of compartments, 4 (McMein and Washburn, Thompson), 5 (Burt), 6 (McMein and Washburn, and our own experiment, pp. 50ff.), 8 (McMein and Washburn), 10 (Bergström), 12 (McMein and Washburn); the packs contain 10 cards of each stimulus, except those of Bergström which contained 80 cards, and our own (see pp. 75f.) which contained 50.

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[1] Dresslar: Some influences which affect rapidity of voluntary movements. Am. Jr. Psych. 1892. 4:514ff.

[2] Bergström: Experimental study of some of the conditions of mental activity. Am. Jr. Psych. 1893-4. 6:247.

[3] Bergström: Experiments upon physiological memory by means of the interference of associations. Am. Jr. Psych. 1892-3. 5:256ff.

[4] Bergström: Relation of the interference to the practice effect of an association. Am. Jr. Psych. 1893-4. 6:433ff.

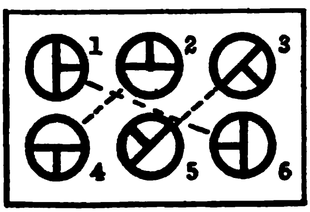
[4a] Brown: Habit interference in sorting cards. Univ. Calif. Pub. in Psych. 1914. Vol. I, No. 4.

[5] McMein and Washburn: Effect of mental type on the interference of motor habits. Am. Jr. Psych. 1909. 20:282ff.

[6] Bagley: On the correlation of mental and motor ability in school children. Am. Jr. Psych. 1900-1. 12:195.

Reaction with discrimination and choice is probably more variable in its processes, in the work of the same reagent as well as in the work of different reagents, than is simple reaction, since there is more psychial process interpolated between the stimulus and the movement, and variability in reaction experiments varies directly with the amount of interpolated process.[88] But the variability may be such that two scores still belong to the same kind of act as is not the case in simple reaction when one of them is of the muscular and the other is of the sensorial type. Yet even here the scores may also be incomparable because the acts are different in kind.

Each pack of fifty cards in this experiment was made up of six symbols shown in the accompanying plate of the compartments according to which arrangement they were distributed (see Appendix B. Figs. 1, 2, p. 288).



In the cognition of the smybol, the diameter was seen by Cr. and Wf. as classifying the cards into vertical, horizontal, and oblique, pairs; by others as merely forming the base of a pointer. The radius was accepted as a pointer by all, except Ly., who named the location of the filled half of the circle, and He., who named the location of the blank half, and was interpreted as pointing right or in, left or in, up or out, down or out, down-oblique or slant down, and up-oblique or slant up; Ly. and He. used the same terms of direction. The cognition of the symbol was especially difficult for Ly.

These terms of direction served to locate the three pairs on the cabinet, in the scheme shown above by the connecting lines,

[7] Burt: Experimental tests on general intelligence. Br. Jr. Psych. 1909. 3:136.

[8] Thompson: Psychological norms in men and women. Univ. Chicago Contrib. to Phil. 1903. 4: No. 1. 15.

[9] Kline and Owens: Preliminary report of a study in the learning process, involving feeling tone, transference, and interference. Psych. Rev. 1913. 20:206ff.

[88] *Vid.* Külpe: Outlines, 422; Oehrn: Psychol. Arbeiten, 1:131-2; Alechsieff: Phil. Stud. 16:24.

for most of the reagents (Mn. Le. Rt. Ly. He. Cr. Wf. Dn.) before the first test was over; Sl., Ms., and Fr., differed, in that the latter two had formed no scheme in the first test, and the former merely formed a mnemonic device to hold the two rows; as, upper row has two radii East and one North, lower row has two West and one South (map directions), without further placing of either pairs or single cards.

Individual variation in the process of distributing was considerable.[89] As is indicated above there were some marked differences in the main outlines of recognizing the symbols and of forming a scheme of the compartments. But even where the main outlines were similar, great variation obtained in the detail of the development in the course of the tests, so that, strictly speaking, no two averages are measurements of precisely the same mental processes. This variation consists in

(a) Differences in the predominant imagery (verbal, visual, kinaesthetic) used in cognition of the symbol and in locating its compartment; in consequent variation in the number of steps in placing a single card (as, 1—visual impression of the card, 2—verbal image accompanying its cognition, 3—visual or verbal image of the compartment, 4—kinaesthetic image of movement of arm to that compartent, 5—visual impression of the compartment, 6—impulse of movement; or, merely steps 1, 3 and 6).

(b) Varying dependency of the imagery used as a cue for the movement, upon a definite memorial scheme of the compartments, or upon random memorial elements of preceding sortings.

(c) Relative adaptability of the scheme adopted (Sl.'s was particularly unwieldy).

(d) Facility in perfecting the scheme.

(e) Facility in superseding it with automatic coördinations.

On account of these individual variations in the process of distributing, at any given point in the tests, not only did the schemes differ in detail, between the individual reagents, but they varied in degree of completion, resulting in varying amounts of primitive and mechanical matching of cards and labels, or in varying amounts of spontaneous sorting from perfected or

[89] *Cf.* Individual variation reported by McMein and Washburn (*op. cit.* p. 283).

from automatic coördinations. Some reagents (Mn. Dn. He. Cr. Wf.) developed a scheme early, and had the process partly automatic before the fourth pack of the first test was sorted; others (Sl. Ms.) did not get a scheme well developed at all, or only at the end of the first test (Fr.).

Many other individual variations in processes could be noticed; such as, (a) effect of sequence upon placing a card—one reagent prefers the succeeding card to belong to the same pair (Cr.); another prefers any other (Rt.); (b) relative preference for the three pairs—to one the oblique is easiest (Rt.), to another it is the hardest (Ly.), etc.

Besides variation in the process, there were variations among the influences upon it:

(a) Emotional—The sorting was vexing and disliked (Mn.), or disagreeable (He.), caused nausea and trembling (Ly.), or was interesting (Le., Wf.), or agreeable (Cr. Sl.), or indifferent (Rt.), and each effect contributed toward the attitude with which the reagent came to the experiment.

(b) The anxiety for speed varied.

(c) Physical causes—such as, "sticking of cards" (Mn.), or stiffness of cold hands (Wf.).

(d) Conditions of health—Ly., He., Cr., were fatigued for their final test, and Wf. was nervous; and Rt. and Al. were less alert than usual.

Since it is our interest to compare averages of tests separated by a long interval of training or of rest, still other variations are of great importance: Those resulting from the different degrees of reproduction, in the final test, of the schemes or of the coördinations formed in the first test. Some of the reagents (Ly., Al., Fr., Wf.) had them well in mind and could use them early in the final test; others (Le., Rt., Sl., He., Cr.) had practically to begin anew, recovering the effects of their former experience in varying degrees and at varying points in the final tests; and with both classes there was variation in respect to further development, particularly on the part of the latter. whose developments occasionally conflicted with returning details of earlier processes. The combined practice of both tests

was not sufficient to lead to automatic coördinations to any considerable degree, and all averages include practice-effect.

The development of processes through practice in the tests may be illustrated by the following record from the introspections of Cr.:

First Test

Pack 1. Matched cards with labels of the compartments continually. No compartments placed; pairs of symbols becoming distinguished.

Pack 2. Some cards distributed from memory of position from distributions recently made; some from a developing scheme of the compartments, which is now drawn from memory (correctly) with some hesitation: The compartments are grouped in pairs (according to the dotted lines in the plate a few pages back) determined by the direction of the diameters: Pair 1. (positions 1 and 6) Are verticles and occupy the opposite corners; radii in. Pair 2. (positions 2 and 4) Horizontals; oblique pair to the left; radii out. Pair 3. (positions 3 and 5) Obliques; oblique pair to the right; radii difficult, but such that I may classify "middles up" (referring to positions 2 and 5).

Continuity of attention to the process and deliberately holding the parts of the developing scheme constituted a persevering 'anlage.'

Pack. 3. Worked the scheme in about tenth the time; sorted some by exclusion; *e.g.*, horizontals belong to compartments 2 and 4; have a horizontal in hand, match with 4 and throw it into 2 without looking at the latter's label; but the process is almost wholly matching.

Pack 4. Scheme comes easier; though instead of working outright without matching, it simply facilitates matching. About an eighth of the time it works adequately alone.

Final introspection. Chief hindrance to the sorting is losing calm control of the partial application of the scheme and of its extension. This does not seem to depend so much upon the intensity of the attention (which the process seems to keep high) as upon its distribution so that the memorial factors are kept sufficiently in process, which is very difficult; matching is easier. Some strain, mental and in left hand. Rather agreeable. (3 errors in the 200).

Final Test

c 1. Recognize symbols as familiar, but had to work
eme of cabinet; some old classification returns, but new
zation begins to supplement it: Pair 1 (positions 1, 6)
Pair 2 (positions 2, 4) "Up" and "down"; Pair 3.
ry, "Down" and "up." But must glance at the cabinet
ually to assure myself of correctness of compartment.
c 2. Scheme did not develop so satisfactorily as it prom-
for at first the process did not require glancing at the
hen had to glance to avoid having to wait on memory,
resulted in confusion to the memorial element and a
to matching. (Best principle would have been to depend
memory, even at occasional loss of time, thus avoiding
ion and retaining scheme). Application of scheme isn't
: sometimes mechanical conception of direction, some-
incipient naming according to scheme, sometimes simply
ng.
e change in Pair 2. from "Outs" to "up" and "down"
d in erroneous application of "in" to them, causing 2
)
c 3. (Tired; have had a wearing day.) Scheme in
art of series took on the following simplification: Pair 1.
on 1, 4) "in"; Pair 2. (positions 2, 5) "up"; Pair 3.
ons 3, 6) "down." But after working a short time it
and I was compelled to resort to matching. (Probably
e of conflict with the old pairs, and lack of energy in
g memorial elements firm).
c 4. Scheme worked better; I depended upon it. Feel
could make great headway in the next few packs, for
eme is not fully mastered, but during this pack it de-
l rapidly. Instead of the old incipient pronunciation of
ss-word, the cards are placed by a more facile cue:
hetic imagery of the meaning of the class-word.
consciousness of any influence of training (on memory
s).

pite of all the degrees of variation between the dif-
reagents, the general experience was similar—reaction
iscrimination and choice—and, since almost all reagents
ped or used the same methods in the final test that they
ped in the first, their results may, with reservations made
s by the above discussion, be compared. The results of

two reagents are disregarded: those of Wf. and Fr., control reagents because of Wf.'s "mental practice" on the test, and Fr.'s review of the compartments and the perfecting of a scheme, between tests, when they should have had no practice.[90]

Initial efficiencies ranged from 79.0-105.4 seconds per 50 reactions, and they fall into four groups around averages of 80, 87, 95, and 105 sec.

The results of the reagents who maintained and developed their old methods, in per cent of decrease in time, are:

	Regular	1st Control	2d Control
Group 1	He. 23	Ms. 10	Dn. 13
	Le. 12		
Group 2.	Mn. 22		
Group 3.	Rt. 15		
	Ly. 21		
	Cr. 22		
	Al. 27		
Group 4.	Sl. 4		

The more important variations affecting these figures are: Le. took her last half of the final test 14 days after the first half, which deprives it of the practice-effect shown by the other reagents who took their's two days after. The interval between the first and final tests was much shorter for Al., which no doubt contributed somewhat to his improvement; on the other hand he was less alert than in the first test. Rt. complained of a "muddy" attention in the final. Sl.'s scheme (map directions) was so unwieldy that in his final test his efficiency fell back to its initial position and he had to cover again the ground he had covered in his first test; this is one illustration of the fact that greater "room for improvement" cannot always be predicated upon low initial capacity (his was the lowest in the series).[90a]

From the table it appears probable that 10% improvement may be expected in this test as a result of practice-effect upon itself;[91] that 10% more was contributed by the training on other material.

[90] Mental practice was shown by Johnson (Experiments on Motor Education. Studies from the Yale Psych. Lab. 1902. 10:87) to facilitate simple reaction to sound.

[90a] On this matter, see footnote 139, pp. 222-3.

[91] This supposition is supported by the evidence afforded by the former

principal factors of improvement seem to be:

A more automatic use of the memorial elements of the ethod from the beginning (Al., Ly.) or soon after the ing (Mn., Le., Rt., He., Cr.) of the final test.

Some further development of the old scheme (Al., Cr.), gh in this there was conflict between the new and old its.

A readier apprehension of the symbol (Ly., for whom been particularly difficult.)

manner in which training affected the test is a matter othesis and might be offered as follows:

training on the tachistoscope heightened sensitivity for impressions, applicable to cognition of the cards; all the g in unequal degrees heightened reproductivity of ry, applicable to the memorial elements of the scheme; chistoscopic training and the learning of 12-letter-rect- exercised coördination of part-processes, applicable to nating discrimination and reaction; the training on the y schemes exercised the continuous attention and the uction of memorial elements, demanded in this test, and ining involved habituation to distraction which would be ble here.

ew applications of former experience may be noted as ex- of transference and spread of training: Mn. and Wf. students of higher mathematics; they were assisted im- ely to the formation of a scheme by reason of the per- relations of the radii; in contrast to this, Le. did not until the fourth pack of her first test that the radius l a right-angle with the diameter on the oblique pair of ls, which relation was then of assistance to her. Sl. it his unwieldly scheme from the class-room.

in Card-Sorting (see Table XXV in Appendix A); in which, al- it was probably benefited by preceding training in Typewriter-Reaction, tice-effect of the first four packs upon the second four was, in per improvement,

Cl. 0 Al. 17 Cr. 12 Bs. 5

ond four packs were distributed the next day after the first four by Al., three days after by Cr., and in the same hour by Bs. Al., Cr., are Al., Cr., and Ms. of the present experiment.

(5) *Typewriter Reaction*

Typewriter-reaction (see p. 76) engages the same essential processes as card-sorting, its chief difference lying in more apparatus and in the necessary changes in forms of stimuli and movements. This form of reaction was used by Bair[1] in the study of the practice curve and interference, and in our own experiment on "Reaction with Discrimination and Choice" (pp. 50ff); it was selected as a type of mental work by Seashore[2] for the convenient measurement of which he devised a special apparatus—The Psychergograph.

This test involved but four coördinations of stimuli and reactions, and thus permitted a more rapid reaction, a slower practice-effect,[92] and a greater degree of automatization, by the end of the final test, than was possible in the card-sorting test.

The order of the letters, from left to right, was *a-t-e-n*. The cognition of the letter as it appeared was not merely a perception of the letter, but an apperception of it as belonging to a certain position, to a certain key, or to a certain finger. This process varied considerably in its dominant imagery:

(a) Visual purely (Rt., He., Cr.).

(b) Sound image 1) of the phonetic value, or 2) of the name of the letter.

(c) Kinaesthetic image of the letter's sound or name (Le. Ly. Wf.); or of the movement of the eye toward its position (Wf.).

(d) Combination of the above, usually accompanied by actual incipient movement of the vocal organs in pronouncing the sound or the name of the letter, or movement of the eye or arm and fingers in locating the letter.

The placing of the letter necessary for carrying out its appropriate reaction usually involved a mechanism of some sort serviceable for keeping the order of the letters clearly in mind and the reaction to each ready. This also varied greatly:

(a) Continual repetition, in inner speech, of the letters in

[1] Bair: The practice curve: A study in the formation of habits. Psych. Rev. Mon., 1902. 5: No. 2.

[2] Seashore: A method of measuring mental work: The psychergograph. Univ. of Iowa Studies in Psych. 1902. 3:1-17.

[92] The average time of the initial 50 reactions in card-sorting was 106 seconds; in the typewriter-reaction, 50 sec. The average practice-effect in the first test in the former was 32%; in the latter, 14%.

their order (Sl. Mn.), sometimes assisted by a mnemonic device, as "Aetna" (Ly.).

(b) Classification of the letters, to hold their positions without repeating them in their order:

1) Left, a-t; right, e-n (Rt.).

2) 1, 2, 3, 4; vowels odd; consonants even (Mn.) or vowels left, consonants, right, and alphabetic extremes on the left hand (Wf.).

3) Terminals a—n; t belongs to a; e to n (Le.).

4) Alphabetic order of a-t, of e-n, and of a-e (Wf.).

The position referred to the keys (Le., Rt., Sl., Ly., Wf., Dr.) or to the fingers (He., Cr., Wf. 2); in case it referred to the former, the finger was sometimes removed and the key glanced at to verify a judgment or to restore the order of the letters to the memory (Ly., Sl., Wf.).

Besides the foregoing causes for variation in the results, there were some others peculiar to the task:

(a) Anticipation caused premonitory reactions which resulted in errors and confusion (Le., Ly., He., Sn.); the same effect is caused by rapid rhythm when the process has become largely automatic (He. Cr.).

(b) Those who formed coördinations with the keys, often had difficulty in the control of their fingers (Le., Ly., Wf., Dr.); the difficulty also occurred when the scheme paired the letters into right and left groups and operated through kinaesthetic imagery in the arms, while the order of the letters in each group was determined by visual imagery (Rt.).

(c) The mental tension involved, sometimes produced dizziness and nausea (Ly.).

(d) The action and noise of the typewriter is so different from the type-bar machines that it was very distracting to some of the reagents who were typists (Rt., Sl., He.).

As a result of the influences of these factors of variation, the task was performed in many different ways by the respective reagents; and the essential method sometimes changed during the tests of the individual reagents.

The former gave rise to, and may be said to be indicated by, great variation in initial ability, ranging from 36.4-67.7 seconds,

which shows a preference for three types: one at 40 seconds per 50 reactions (Mn., Rt., He., Cr., Ms.); the second at 55 seconds (He., Wf., Sn., Dn.); and the third at 65 (Sl., Ly.).

If the change in the individual reagent's work occurs in an early series of his first test, it lowers his average for that test and decreases the difference between the results of the two tests; if it occurs early in his final test or late in the first test it operates in the opposite direction. The change is sufficiently radical in the case of two reagents to throw out their results: Mn. changed from repetition of the series of letters, in the beginning of her final test, to the use of a classification; Wf., at the beginning of his final test, changed from "verbal image—key" to "verbal image—finger," made a radical change in method, and just before taking the final test took up practice in typewriting.

The improvement, in per cent of decrease in time, made by the other reagents was:

	Regular	1st Control	2d Control
Group 1.	Le. 14.6	Ms. -.07	
	Rt. 12.4		
	He. -6.1		
	Cr. 4.9		
Group 2.			Sn. 13.9
			Dr. 13.6
Group 3.	Sl. 10.4		
	Ly. 4.7		

Since the reagents in groups 2 and 3 did not attain in their practice in the two tests an efficiency equal to that of the reagents in Group 1 at their beginning, inspection of results will have to be limited largely to the latter.

As to the practice-effect of the test upon itself for Group 2, it must be about 14%; we have, unfortunately, no trained reagents whose results can be used in comparison to test training-effect. For Group 1, however, we are able to make an estimate. From the data of the old investigation (see Appendix A, Tables XXI p. 275 and XXIII p. 276). It is calculated that continuous practice in work identical with this test, for reagents whose initial efficiencies place them in Group 1, resulted in a loss of 7% (Cl.) and 10% (Cr.), and a gain of 0.4%

.); and the effect of a free interval[93] of 45 days, after
ice on 36 series, was a gain of 4.4% (Mn.). Since our
ice in the first test amounted to but 4 series, and the interval
twice as long, it is possible that Le. Rt. and Cr. were
ited from 4% to 10% by their training.
is benefit could be described, however, only in general
s: (a) The coördinations became more nearly equal in
gth, as is shown by decrease of the smaller variations;
Steadiness of attention increased, as is shown by decrease
ie number of 'balks,' (except for Cr., for whom there
ncreased distraction in operating the recording apparatus);
(c) Control of the memorial element increased, as is shown
ie decrease in the length of the 'balks.' (a) is shared
n., Sl., and Ly.; (b) by Sl.; and (c) by none of the other
nts. The training of the tachistoscope may have con-
ed higher sensitivity for the visual stimuli and better
ol in distributing the attention over part-processes; and
raining on memory schemes may have contributed some-
toward better control of the memorial element.
iat distinguishes the three types, as intimated above, are
ences in the performance of the task: Group 1 begins
a fairly direct coördination of either visual impression, or
ound or kinaesthetic image into which it is converted, and
ey or the finger; and reactions early begin to become more
ss automatic (Rt., He., Cr., Ms.). The first effect of
ce is likely to be loss in efficiency, as recorded in a preced-
aragraph, due to evolving a scheme, more or less simple,
is to be instrumental, if practice is continued long enough,
ecting automatic coördination of visual impression and im-
of finger. Rt. began with (1) visual impression, (2)
esthetic image of movement in the right or left arm, (3)
image of key, (4) impulse of finger, and dropped (2)
3). Cr. began with (1) visual impression, (2) verbal
, (3) impulse of finger, and dropped (2). Schemes were

e effect of the 80-day interval upon all our reagents was an average
tween the last series of the first test and the first series of the final
6% of the initial capacity.

very simple, relating the stimulus to kinaesthesis of arm or fingers; for Cr. this consisted in 'feeling' the letter in the finger. There was no alphabetic, logical, or phonetic classification.

Group 2 begins with a more indirect coördination of stimulus and reaction, by interpolating retarding accompaniments of cognition and a more or less elaborate or complex classification of the letters, or an inefficient memorial representation of them, so that the reacting process is circuitous. Wf. began with (1) visual impression, (2) verbal image, (3) kinaesthetic image of eye-movement to key, (4) impulse of finger, and dropped (3). Schemes were complex, alphabetic, phonetic, and logical.

Group 3 adds to these interpolations some especially inefficient process, probably usually of method. Sl. and Ly. matched letter and key, for which the reacting finger had to be removed and returned before the movement could be carried out. The process is divided into two distinct acts: cognition of letters and searching for keys.

The elements constituting the process of any reagent are at first selected from his stock of experience, and then are changed in accordance with the reagent's adaptability. No doubt Ly., who was not especially slow in card-sorting, came to the test with a strong sensory set of consciousness in accordance with her training in reaction to sound, for she complained that she gave her chief attention to the stimulus and could not get it directed upon the keys; the location of the key was either observed or remembered after its use was called for. Improvement was made, and many of the reactions were later carried out without involving a glance at the key, but the choice of the reaction remained a more or less distinct act following the discrimination of the stimulus.

Although the course of practice varied with the type, the general effect involved (a) the reduction of the interpolated process, (b) the simplification and finally transcendence of the scheme, (c) increase in partly or fully automatic reactions. The end of continued practice would be the automatic coördina-

of visual impression and finger impulse, into which all s would merge.

(6) *Controlled Reaction*

e Controlled Reaction involves further interpolated mental process be- n stimulus and reaction, namely the referring of the stimulus to one of lasses which determines the choice of the reacting movement. It has used in Jastrow's[1] laboratory under the name of "Classification Time"; onosyllablic words of each of the three grammatic classes, nouns, verbs, djectives, were used in irregular order as stimuli. Our test (see p. 77) ws Münsterberg[2] in using as stimuli the names of poets, philosophers, smen, scientists, and musicians. Both of these researches, however, used hronoscope for measuring the individual reactions, while we used the watch (except in the case of Cr. who reacted as rapidly as possible to uccessive stimuli).

n this reaction there were five coördinations between class- e and fingers, but the class-name could be got only by sifying the stimulus; as, Newton, "scientist—4th finger"; art, "musician—fifth finger"; *etc.*

he variability of processes may be indicated by the following sification of methods:

a) The auditory impression of the name may be followed a kinaesthetic image of the movement in the appropriate er for the class to which the name belongs; and, as a result practice, by a kinaesthetic impression from incipient move- t in the finger, and later by the impulse of the finger in tion. Attention is mainly upon classifying the name, and, irst, upon reviewing the class-finger coördinations. The dination may be effected by conferring the professional air, osition, or attitude of the class upon the finger (Cr.).

b) Or the auditory impression of the name may be followed he pronunciation of the class-name, in the effort of classifi- on; then a judgment determining the class; then a choice he appropriate finger; then the impulse of the finger (Ly.).

c) The coördinations may be more or less strong so that attention may be given to the classification (Mn., Le., Sl., Le., Re.); or the coördinations may be weak and demand t of the attention (Rt., He., Ms.); or both may be equally

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[1] astrow, Morehouse, & Harper: Classification Time. Am. Jr. Psych. 1891. -415.

[2] ünsterberg: Beiträge für experimentelle Psychologie. 1889. Heft 1:85.

difficult so that the attention oscillates between more or less separate acts (Ly.); or both may be equally easy so that the attention by quick oscillations can carry them both along at the same time (Cr.).

(d) The coördination may involve a scheme of the classes on the fingers (Le.) or in the positions the fingers occupy (Rt.), or the classes may be simply held in sequential order (Wf.).

The interval between series, or between reactions, may be used in reviewing the coördinations (Wf., He., Ey.), or in keeping the mind clear, in order to avoid anticipation of classes (Ey.).

Some further intimation of the variability of the processes, not only between different reagents, but with the same reagent, (as attention must oscillate from one weak part to another of the complex process) is given by the nature of the errors. They appear to have been owing to at least four principal causes:

(a) False classification through their ignorance or confusion (Mn., Ly., He., Sl., Ey.).

(b) Coördination may be weak and the wrong finger be unconsciously used (Mn., Sl., Ly., Ms.), or confused with another (Wf.).

(c) Control of the fingers may be at fault; especially likely with the corresponding fingers of the two hands (Le., Rt., Ms., Ey.).

(d) Automatic reactions may take place before classification is made, sometimes following the pronunciation of a class-name in trying to classify the man (Le.), sometimes as a result of strong expectation for a certain class (Ey.), or of a rhythm too fast to control (Mn., Ms.).

(e) A few errors occurred through misunderstanding the name, as, Hayden for Hegel, Coe for Poe, Verdi for Virgil, (Sl., Ms.).

The greatest number of errors were made by those who put their attention mostly upon classification.

Among the reagents there was considerable variation in initial capacity; it ranged from 1.34-2.44 seconds per reaction, for 50 reactions, and falls into three groups: 1.4 (Mn., Ms., Wf.); 1.7 (Rt., Sl., Ly., He., Cr., Ey.); 2.1 (Le., Re.).

Analysis of results and examination of introspections, how-

ever, do not reveal any simple characterization for the respective groups. That they are valid is attested by the 'reduced' time (total time minus free reaction, or cognition time), which would change but two reagents, by putting Rt. in group 1 and Ly. between Groups 1 and 2.[94]

The improvement in per cent of decrease in time was:

	Trained	1st Control	2d Control
Group 1.	Mn. 19	Ms. -7.0 Wf. 1.8	
Group 2.	Cr. 14 He. 11.5 Rt. 11 Sl. 1.5 Ly. -5.6		Ey. 6.7
Group 3.	Le 26		Re. 20.8

Mn. and Wf. gained slightly, and Ey. considerably (7-16) in errors; the latter owing to her classification of unknown men as scientists, the least known class.

If the processes in the respective groups can be considered equivalent, and equally susceptible to improvement, some advantage of training may be presumed from the tachistoscopic, and memory, training and from learning 12-letter-rectangles. In what way the training may be presumed to influence the test is a matter of conjecture: The training on the tachistoscope and learning 12-letter-rectangles demanded keen attention upon signal for a short time, and required its distribution over the part-processes involved; the former, and also the latter in the case of Rt., heightened reproductivity of imagery. The memory training may have contributed to steadiness in keeping the memorial element of the process ready to the end of forming automatic coördinations between class and finger.

Improvement consisted in abridgement of the interpolated processes between stimulus and reaction. Some of the specific elements in this were: (a) reduction of the pronunciation of the class-word to a kinaesthetic image, or at least to incipient

[94] This is due to the fact that they took a disproportionate time for the mechanical and perceptive part of the reaction; the average was .6 or .7 sec., and they took .97 and .99, respectively.

movement (Mn.), or even to the professional air of the class the attitude of which is coördinated with the finger (Cr.); (b) effecting coördination between class and finger by use of a scheme; Rt. put poets and musicians on the ends, statesmen in the middle, and philosophers and scientists in the intervening spaces, holding the scheme visually; then the scheme became more kinaesthetic and less conscious; (c) the habit of using the intervals between series for reviewing the coördinations so as to be about equally prepared for all classes (He.), or particularly for those which have not been recently reacted to (Wf.); or for keeping the mind clear so as not to be influenced by expectation (Ey.); (d) attention steadied over the whole process so as to keep it under better control (He., Cr.).

Those who fared worse in the final test than the rest gave their attention to the classification mostly, which left the coördinations relatively free from practice-effect. Ms. lost some on all the classes, but most on poets, scientists and musicians; Sl. and Ly. made gains on poets, scientists and musicians, but lost disproportionately on philosophers and statesmen, that is, their coördinations became more unequal in strength than they had been in the first test.

None gained equally on all classes, and the greatest inequalities of gain were made by Le. who reduced her time almost wholly upon philosophers and scientists, classes that had taken on the average more than twice the time required for the other classes. But the effect of the interval on all those who gained much was to even up the strength of the various coördinations.

(7) *Sound Discrimination*

Sensible discrimination ranks with reaction time as a device or procedure in the psychological laboratory for the study of mental processes. Külpe[1] notes its high dependence upon attention, Titchener[2] suggests it as a gross measure of attention, and Spearman[3] concluded, from correlational data, that it is most closely related to general intelligence. In the laboratory it has been used in the study of memory of lengths of lines (Hegelmaier[4]), of memory and recognition of tones (pitch) (Wolfe,[5] Angell and Harwood,[6] Angell[7]), of intensities of sounds (Lehmann,[8] Angell[9]), and of shades of gray (Lehmann,[10] Angell[11]); and for the analytical study of mental imagery (Bent-

/hipple[12]). It has been used as a mental test in determining power to inate differences in pitch (Gilbert,[14] Seashore,[15] Wissler,[16] Thomp-Spearman,[3] Krueger and Spearman,[18] Burt[19]), shades of gray, (Thomp-nd our own test on pp. 42ff.) and color (Bennett[20]). The test is rdized in Whipple's manual,[21] which gives an account of its use and its

Since qualitative variability in performance may depend in its con-spects upon the nature of the differences to be discriminated, it must embered that our test (see pp. 77f.) involves differences in intensity.

ce an analysis of the various processes of this test has y been made in a former experiment on Discrimination,[95] a characterization of individual performances is more

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pe: Outlines of Psychology. 1901. 38, 429.
chener: Lectures on the elementary psychology of feeling and attention. 279.
arman: "General Intelligence" objectively determined and measured. . Psych. 1904. 15:279.
gelmaier, in Vierordt's laboratory about 1852 (Quoted by Bergström: . Psych. 18:211).
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mann: Kritische und experimentelle Studien über das Wiedererkennen. tud. 1892. 7:204ff.
gell: On Judgments of "Like" in discrimination experiments. Am. Jr. 1907. 356ff.
mann: Ueber Wiedererkennen. Phil. Stud. 1889. 5:96ff.
gell: Discrimination of shades of gray for different intervals of time. tud. 1902. 19:1-21.
tley: Memory image and its qualitative fidelity. Am. Jr. Psych. 1899.
ipple: An analytical study of the memory image and the process of nt in the discrimination of clangs and tones. Am. Jr. Psych. 1901. f, and 1902. 13:219ff.
pert: Experiments on the musical sensitiveness of school children. from Yale Psych. Lab. 1893. 1:80-87.
shore: Hearing ability and discriminative ability for pitch. Univ. of tudies in Psych. 1899. 2:55-64.
ssler: Correlation of mental and physical tests. Psych. Rev. Mon. 3: No. 6.
ompson: Psychological norms in men and women: Univ. Chicago . to Phil. 1903. 4: No. 1. Pp. 72, 81.
ieger and Spearman: Die Korrelation zwischen verschiedenen geistigen gsfähigkeiten. Zeits. f. Psych. 1907. 44:87.
t: Experimental tests of general intelligence. Br. Jr. Psych. 1909. 23.
nett: Formal discipline. 1907. P. 59.
ipple: Manual of mental and physical tests. 1910. Of brightness, 159; n, 180.

47f.

minutely made in a following experiment in which sensible discrimination constituted the training,[96] only sufficient analysis is made here to indicate the fact of variation in processes.

(a) The sounds may be naïvely compared as external events (Mn., Vg.) sometimes accompanied by visual imagery of the experimenter's production of the sound; as, imaging him striking the desk with a pencil; and the weaker sound may be imaged as coming from a nearer source.

(b) The image of the first may be compared with the sensation of the second (Mn., Rt., He.).

(c) The effect of the sounds on the body may be compared; as, the placing of the kinaesthetic auditory image higher or lower in the head (Le.), or the blinking of the eyes (Ly.).

(d) The reactions to the sounds may be compared; as, movements of the hands, head, throat and tongue (Ly), nodding the head (Mn.), or breathing out forcibly like an axeman when striking the blow (He.).[97]

(e) Or there may be no imagery, and the effects in the attitude compared (Rt., Wf.).

(f) And the sounds may be represented by verbal classification (Ly., Ms.).

Certain method may be employed; as, holding the breath and closing the eyes (Le.), holding the ear in a certain position to catch the sound (Sl.), making allowance for the second sound seeming relatively louder because of its getting closer attention (He.), or because it is accented by an iambic rhythm (Wr.).

The process further varied because of certain distractions; as, external noises (noted by almost all reagents), distracting thought (Wf.), difference in quality of sounds (He.), expectation (Rt., Le.). (Many noticed the difference in quality of loud and weak sounds as appearing high or low in pitch, metallic or wooden, but did not consider it a distraction except in judging "like"—Mn., Rt., Ly., He., Ms.).

[96] Pp. 199ff., 206ff.

[97] Kuhlmann (On the Analysis of Auditory Memory Consciousness. Am. Jr. Psych. 1909. 20: 194ff.) found the motor processes used in imitating the sounds to be the most frequent factor in the recall of details of sounds of familiar things.

That the essential process itself varies with the individual reagent is indicated by introspective notes that the norm varied in intensity (Rt., Ms.).

Some variation undoubtedly occurred by reason of unfamiliarity with the (customary) symbols used in recording the judgments (Le., Ms.), (*vid.* Appendix B. Fig. 8, p. 290).

Although the processes varied with each individual, there is not sufficient introspective evidence at hand to indicate any radical change between the final and the first tests.

Initial capacity ranged from 43%-73% of right judgments, and may be distributed in three groups:[98] 70% (He., Wf., Sl.), 57% (Mn., Le., Rt., Ms.), and 45% (Ly., Vg., Wr.).

Improvement made in per cent of initial capacity was:

	Regular	1st Control	2d Control
Group 1.	*Sl. 18 65 51 He. 0 0 0	Wf. -4 -6 -46	
Group 2.	Mn. 41 50 50 Le. -10 -5 -58 *Rt. 9 14 35	*Ms. 5 22 46	
Group 3.	Ly. 23 25 26		Vg. 30 35 37 Wr. 25 21 21

* Foot-note 98 indicates that these reagents fall into lower classes, for the 2d and 3d columns.

The first column of per cents refers to judgments on all four intervals above and below the value of the norm, where D = 0; the second column, to judgments on the first two intervals above and below the value of the norm only; the third column to change in the "Difference Limen."

[98] The initial capacity to judge differences between the stimuli of the first two intervals above and below the value of the norm, also varies, from 29% to 58% R cases, and would also classify the reagents into three groups around the averages of 53%, 43%, and 34%. But it would change Sl. to the 2d group, and Ms. and Rt. to the 3d group.

Also the "Difference Limen" (that point between 0 and 4 intervals from the value of the norm at which 50% of the judgments are right) of the reagents ranges from 0.97 to 3.20; and classifies the reagents into three groups just as capacity of discrimination on the two intervals above and below does; except that it places Ms. between Groups 2 and 3. (These three groups: 1.2, 1.7, 3.)

About Group 1 nothing can be said except that initial capacity was remarkably high and perhaps no improvement could be expected. Group 2 shows several consistent gains: Mn. in the three columns and Sl. in the 2d and 3d columns. Abstracting from the results of Group 3, where gain should be relatively greater, Mn. and Sl. seem to have been benefited by their training. Mn. was exercised on minimal stimuli in the field of vision, and may be expected to show some profit from it in discrimination; and both Mn. and Sl. may have applied some training-effect in better attention for the moment, and in better reproduction of imagery.

Le.'s results are peculiarly clouded. They do not show the improvement she made in discrimination, for, although half of her series in the first test yielded 4 R cases each, and half of her series in the final test yielded 6 R cases each, for some reason which her introspections fail to explain, a fifth of the latter yielded but 2 R cases each. It is possible that the erasures in her record indicate confusion of symbols; in which case her irregular results are accounted for.

(8) *Memory of Sounds*

The memory span, which is found by noting the longest series of digits or letters perfectly reproduced from a single presentation, usually auditory, is noted by Pillsbury[1] as one of the customary measures of attention, and Külpe says that "attention produces its maximal effect in the reproductory sphere."[2] Our tests in memory of serially presented members differ from the memory-span test in measuring the average number of members reproduced from a single presentation of a series too long to be completely retained (Methode der behaltenen Glieder, see p. 142). This test of memory of sounds (see p. 78) follows Fracker,[3] and involves the perception and recall of four easily distinguishable intensities of sound. It is known that cognition of intensities of sensations occupies longer time than cognition of qualities, and that discrimination of intensities of sound is peculiarly difficult (Külpe[4]). These facts in addition to the novelty of the task and to the composite character of the auditory image for clangs, as found by Whipple,[5] are calculated, in spite of the simplicity of the stimuli, to cause great qualitative variation in the processes used in the test.

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[1] Pillsbury: Attention. 1908. 84ff.
[2] Külpe: Outlines of psychology. 1901. 430.
[3] Fracker: On the transference of training in memory. Psych. Rev. Mon. 1908. Whole No. 38. Experiment III, pp. 59f.

The four intensities making up the series of ten sounds were identified by the numbers from 1 to 4, in the order of intensity.

Since this test closely resembles one of Fracker's,[99] the analysis of processes and the description of methods used by the various reagents will be of particular interest. His reagents used visual imagery mainly; some of ours used neither auditory nor visual imagery (Wf.).

As the sounds came they had to be cognized, which was done by naming (giving them the numbers 1-4), or by comparing them with each other; the former needed a memory of absolute intensity, and the latter had to be done very quickly, in process, or it had to be left till the whole series had been received. These three methods of receiving the impressions would from the beginning of the experiment necessitate quite different processes, and they were all illustrated by the reagents in this test.

The retention of the sounds was carried out in various ways:

(a) Retained in auditory imagery (He.).
  1) The last few sounds of the series only (Le., Ly.).
  2) In rhythm according to intensity, like chimes (Mn. Gl.).

(b) Retained by kinaesthetic (Wf.), kinaesthetic-auditory (Al., Sl., Ty.), auditory-visual (Ly., Rt.) imagery of the name (number) given to the sound when it came.
  1) Giving a rhythm to the naming (Le., Ms.).
  2) Grouping the numbers (Le., Rt., He., Ms., Wf.).
  3) Using mnemonic aids; as assigning the sounds to a spatial scheme, like numbered steps (Al.),[100] or associating their numbers with the visible numbers beside the blank spaces for the record (Sl., Ms.).

(c) Retained by kinaesthetic imagery of the response to the sounds (Ly.).

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[4] Külpe: *op. cit.* pp. 417-8.
[5] Whipple: An analytical study of the memory image and the process of judgment in the discrimination of clangs and tones. Am. Jr. Psych. 1902. 13:259.

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[99] *Op. cit.* Nine Tones, p. 59.
[100] A favorite method with Fracker's reagents (*op. cit.*, 70-71); Kuhlmann (On the analysis of auditory memory consciousness. Am. Jr. Psych. 1909. 20:194ff.) found visual imagery that accompanied the auditory imagery a frequent means of recall of sounds of familiar things.

The imagery of some of the reagents was of a mixed type (Rt.), and methods varied radically both between and with individual reagents.

As a consequence of doing so many different tasks in taking the same test, the results varied greatly; initial capacity ranged from .3 to .7 average points per series, and fall into four groups of about .7, .5, .4, and .3 points.

Improvement for the reagents who did not radically change their methods between tests, in per cent of initial capacity, was:

	Regular	1st Control	2d Control
Group 1.			Gl. -17.6
Group 3.	Le. 37 Rt. 38		
Group 4.	Al. 52		

Each of these reagents named the sounds as they came; for Le. the first group of four stood out in kinaesthetic imagery, the last two persisted in auditory imagery; but in the very last of the final test a new and more adequate method began to develop—retention of the rhythm of the intensities of the sounds in a series as in chimes. Rt. grouped the names in rhythms and recalled through kinaesthetic and auditory-visual imagery of the names. Al. recalled through kinaesthetic-auditory imagery; his visual imagery is not strong or he probably would have made use of the vague spatial scheme that occurred to him near the end of the first test.

Some of the other reagents made much more loss or gain (Group 1. He. –11, Sl. –3; Group 2. Ly. –16, Ms. 14; Group 3. Wf. 49, Group 4. Mn. 116%), but they all made radical changes in their methods in the final test. Mn., who made the greatest gain, grouped the sounds into three rhythms (4, 4, 2) in the first test; but in the final followed the sounds as in a tune which gave the effect of chimes, the strains of which were remembered and transposed into numbers by comparison after the whole series was received. Sl. simply named the sounds in the first test, but appealed to mnemonic aids in the final, and, for some series, associated the names of the sounds with the visible numbers of their respective spaces on the blank record before him

(the same method that Ms. used in her first and had to change from, when discovered, in her final test) or he associated them with his fingers. Ly., in the first test, reproduced from auditory and visual images of the names of the sounds, except for the last two or three sounds in the series which persisted in auditory imagery, but in the final test she used more kinaesthetic-auditory imagery for the early part of the series and kinaesthtic imagery of response to the sounds for the later members of the series. He., who found it extremely difficult in the first test to (a) name the sound, (b) place its order, and (c) hear the next one, in almost simultaneous process, and who combined kinaesthetic imagery of names with auditory imagery of sounds, gave up, in the final test, the triple process and attempted to get an auditory impression of the whole series, making identification afterward by comparison; and while he stopped in the series with as many members as he thought he could retain, in the first test, in the final he tried for all, which resulted in indefinite grouping and fixing of the members. Wf. introduced in his final test rhythms of three.

The changes that were made in the processes seem to be broadly adaptive, and in no way dependent upon the training during the interval.

The reagents in the table above had practice in fixing and reproducing kinaesthetic and visual imagery of letters, and it is possible (a) that they did not change to other methods because their training improved them in the elements they had already used; and (b) that this improvement accounts largely for the improvement shown in the table. But since there are no comparable records from control reagents at hand, the latter point must be left an open question.

The changes in method were not necessarily beneficial; as is shown several paragraphs above, in parenthesis; half of the reagents making them lost in efficiency.

As to the effectiveness of the respective methods, those who associated the number assigned to the sounds with the numbers of the blank spaces for the record made the largest scores,

Ms. producing a perfect score. The next efficient method was the auditory reception and retention of the whole series as chimes. Neither method involved the memory of sound intensity: The first being merely the memory of associated numbers; the latter, of relations between intensities grouped in a very exceptional manner.

It would seem that the visual forms of imagery employed with greatest success by Fracker's reagents were not necessary forms, but were preferences on the part of reagents who had good visual or kinaesthetic imagery, readily adaptable to the test, and encouraged by the training.

(9) *Memory of Consonants*

Memory for letters, usually consonants orally presented in a series too long to be reproduced from a single presentation (according to Ebbinghaus'[1] Methode der behaltenen Glieder), has been frequently used in mental tests (Jacobs,[1a] Münsterberg,[2] Cattell,[3] Toulouse,[4] Pohlmann,[5] Winch,[6] Bergstrom[6a] Sleight[7]). Our test (see p. 79) is similar to Whipple's Test 38 A (2), Variation (6).[8] The five series of 10 consonants were presented visually with a Jastrow Tachistoscope.

The following is a classification of the more important methods followed by the reagents in this test:

(a) Attention to the series as a whole with the view of retaining the visual imagery (Al., who recalled, however, from auditory imagery).

(b) Naming the letters in rhythms of 4, 4, 2, (Le., Ms); of two's (Le.); of 4, 3, 3, etc.

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[1] Ebbinghaus: Ueber neue Methode zur Prüfung geistiger Fähigkeiten und ihre Anwendung bei Schulkindern. Zeits. f. Psych. 1897. 13:401ff.

[1a] Jacobs: Experiments on "prehension." Mind. 1887 [o.s.] 12:75ff.

[2] Münsterberg: Beiträge zur Experimentellen Psychologie. Heft 4. 1892. S. 121ff.

[3] Cattell: Mental tests and measurements. Mind. 1890. 15:377.

[4] Toulouse: Enquête medico-psychologique sur les rapports de la supériorité intellectuelle avec la névropathie. (Zola). 1896. 207.

[5] Pohlmann: Experimentelle Beiträge zur Lehre vom Gedächtnis. Berlin. 1906.

[6] Winch: Immediate memory in school children. II Auditory. Br. Jr. Psych. 1906. 2:52ff.

[6a] Bergström: Effect of changes in the time variables in memorizing, together with some discussion of the technique of memory experimentation. Am. Jr. Psych. 1907. 18:206ff.

[7] Sleight: Memory and formal training. Br. Jr. Psych. 1911. 4:430.

[8] Whipple: Manual of mental and physical tests. 1910. 366.

1) "Impressing" the letter-names vividly while perceiving.
2) Strengthening the kinaesthetic impressions by serial repetition after each impression (Tn., Ds.), or in groups of four (Mn.)[101]

) Forming associations between the letters through familiar ls, abbreviations, cattle-brands, chemical compounds, etc. , Ly., He.).

) Making syllables by interpolating vowel sounds (Ds.).

production usually involved several kinds of imagery in record; usually the first part was reproduced by kinaesthetic inaesthetic-auditory imagery, or representative imagery ciations), and the last few letters by kinaesthetic or visual ery; occasionally there was reproduction from auditory ery (Ly., Al.). In case both parts of the series (begin- and end) were reproduced from kinaesthetic imagery, the er was the rote effect of repetitions and the latter the tly converted impression.

me of the reagents changed their methods in the final test: hanged from a rhythm of four to a rhythm of two in ng; and in her final recorded the last group, which was ccorded so much attention, first, leaving effort free to the earlier part of the series in kinaesthetic imagery; and impossible to determine whether the disadvantage of the er change is equivalent to the advantage of the latter. Ms., h not consistent in method in either test, made some use of iating letters with their preceding fellows, already re- d, in the first test, but in the final made use of a rhythm in naming. Wf., who relied in the first test upon kinaes- imagery for the main part of a series and visual imagery ne last few letters, made great use of associations for the er and kinaesthetic for the latter, in the final test. Ds. ged from forming syllables by interpolating vowels, in the part of the series, and a visual retention of the last few s, to rapid repetitions between exposures, of all the letters the beginning of each half of the series; as, C, CV, CVJ, 3, etc.

. Müller, G. E.: Zur Analyse der Gedächtnistätigkeit und des Vor- gsverlaufes. Zeitschr. f. Psych. 1911. Erg.-Bd. 5. S. 214.

There was some variation between the reagents who retained about the same methods for their final test that they used in their first. Mn. repeated in groups of four, reviewing after each group, recalling from kinaesthetic-auditory imagery, and occasionally recorded from the bottom up (perhaps from visual imagery). Rt. divided each series into two parts for rhythm, in the first test taking 5 members for the first group and in the final 6, which was recorded from kinaesthetic imagery, and recording the last few letters in the series from visual imagery. Sl. recorded the last letter from visual, the others from kinaesthetic imagery and associations. Ly. made use of associations and reproduced from kinaesthetic-auditory imagery and from visual imagery. He. occasionally recorded the last letter from visual imagery, but most of the reproduction was from kinaesthetic imagery supported by associations. Cr. depended chiefly upon kinaesthetic-auditory imagery for all but the last two letters, which were retained visually; associations occurred occasionally. Al. tried to grasp the series as a whole, evidently a predominantly visual effort, and recorded largely from auditory imagery, as is shown by confusion between similarly sounding letters. Tn. repeated letters in intervals between exposures, each time from the beginning, until repetition excluded perception (at about the 7th consonant); then got the last few letters from kinaesthetic imagery from a single repetition.

Initial capacity ranged from .3 to .7 points, per series, and classifies the reagents into four groups: .7, .6, .4, .3.

Improvement in per cent of increase over initial efficiency, was made by those reagents retaining in the final test the methods used in the first, as follows:

	Regular		1st Control	2d Control
Group 1.	He.	17		
	Cr.	-13*		
Group 2.	Mn.	34		
	Rt.	20		Tn. 1
	Sl.	12		
Group 3.	Ly.	-3		
Group 4.	Al.	99		

*Irregular; due to operator's error.

ere one to consider Ly. as equivalent to a control reagent, she was training in reaction time, it would give some er basis for supposing that He., Mn., Rt., and Al. were ited by their training. The training of all, except He., upon the reproduction of letters exposed as visual impres- . Rt. shows some carrying over of method in the 6-term ping in his final test. The factors of improvement in this are not so different from the factors of improvement in raining:

) Better coördination of the part-processes; *e.g.*, perceiv- and naming, grasping in rhythm, reviewing a rhythmic o hastily before fixing the next; recording and retaining, recording involves kinaesthetic reproduction of different m, also an accentuation of the group attended to, at the ise of other groups retained kinaesthetically. This con- es toward the following classes, but does not account wholly hem.

) Better fixing of imagery.

Better recall.

e last two factors depend upon increased sensitivity and r liability and fidelity of reproduction. Both are affected nditions of attention.

e complete segregation of these factors is not possible the present data, though each is occasionally clear. (a) is n by Mn. in perfect records interspersed with low scores, o kinaesthetic imagery disappearing while recording; (b) wn by Rt. who extends the first group of letters from five to seven or eight, and Al. who extends the first group of es from two or three, to three or four and the last group two to three; and (c) is shown by Mn., Rt., and Sl., in substitutions and misplacings.

nge of method was advantageous to those reagents who it: Group 2. Wf. improved his score 11%; Group 3. 1.2%; Le. 39%; Group 4. Ms. 48%.

(10) *Memory of Numerals*

ory for digits serially presented, usually in auditory form, has been a mental test (Jacobs,[1] Bolton,[1a] Münsterberg,[2] Toulouse,[3] Cattell and ,[4] Ebbinghaus,[5] Wissler,[6] Binet,[7] Pohlmann,[8] Krueger and Spearman,[9]

Sharp[10]); sometimes for the purpose of measuring attention (Bolton,[1a] Binet[7]). Digits were preferred to non-sense syllables by Cattell and Farrand.[4] Our test (see p. 79) is similar to Whipple's Test 38 A. (2), Variation (1);[11] series of 10 printed digits were presented visually with the Jastrow tachistoscope.

Methods varied in their general characteristics as follows:

(a) Repetition 1) of single numerals (Tn., Le., Sl., Ds., Cr.)
2) in rhythms (Le., Ms., Rt., Tn., He., Al.)
3) Naming once.
4) Naming over and over.
3) and 4) are both combined with both 1) and 2).

(b) Grouping (4-place Mn.; 3-place Wf.; 5-p Ds., Cr.).[102]

(c) Apperceptive grouping or relating (Ly., He., Wf.).[103]

(d) Associating with numbers recorded in a preceding series (Ms.).

Recall was through various imagery and was usually complex: Auditory (Mn.), auditory-visual (Ly.), kinaesthetic-visual (Rt., Le., Sl., He.), kinaesthetic-auditory-visual (Cr.), and through associations (Ly., Wf.). Sometimes the disparate imagery supported each other on the same numerals recalled;

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[1] Jacobs: Experiments on "prehension." Mind. 1887. [o.s.] 12:75ff.

[1a] Bolton: Growth of memory in school children. Am. Jr. Psych. 1891-2. 4:362ff.

[2] Münsterberg: Beiträge zur experimentellen Psychologie. Heft 4. 1892. 121ff.

[3] Toulouse: Enquête medico-psychologique sur les rapports de la supériorité intellectuelle avec la névropathie. (Zola). 1896. 222.

[4] Cattell and Farrand: Physical and mental measurements of the students of Columbia University. Psych. Rev. 1896. 3:644.

[5] Ebbinghaus: Ueber eine neue Methode zur Prüfung geistiger Fähigkeiten und ihre Anwendung bei Schulkindern. Zeits. f. Psych. 1897. 13:410.

[6] Wissler: Correlation of mental and physical tests. Psych. Rev. Mon. 1901. 3: No. 6. p. 9.

[7] Binet: L'Étude expérimentale de l'Intelligence. 1903. Pp. 240ff.

[8] Pohlmann: Experimentelle Beiträge zur Lehre vom Gedächtnis. 1906.

[9] Krueger and Spearman: Die Korrelation zwischen verschiedenen geistigen Leistungsfähigkeiten. Zeits. f. Psych. 1907. 44:50ff.

[10] Sharp: Individual psychology: A study in psychological method. Am. Jr. Psych. 1899. 10:351.

[11] Whipple: Manual of mental and physical tests. 1910. P. 364.

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[102] *Cf.*, Müller: Zeits. f. Psych., Erg. Band 5. S. 211.

[103] *Idem.* S. 215; also Knors: Archiv f. d. ges. Psych., 17:340.

:times coöperated in holding their respective numerals
pendently.
ıe following reagents used different methods in the final
from those used in the first: He. added to his 2-place method
aming, an apperceptive element by relating the number to
and he dropped his visual reproduction of the last numbers
series for kinaesthetic imagery. Cr. changed from kinaes-
c-auditory, and visual for the last two letters, to a complex
ping involving 2-place and 3-place numbers, as, " "', " "'.
changed from a rhythm of four to a mere repetition. Al.
ged from a total impression to groups of 4, 6. Ms. changed
ı a rhythm of five to a single naming with effort to associate
numbers with the figures recorded in the preceding series,
h essentially changed the process to memory of associated
. Wf., who had used kinaesthetic imagery supported by
ciations (perceived relationship between the figures in the
s, such as products, squares, cubes, etc.), changed to group-
into 3-place numbers. Tn. and Ds. changed respectively
ı a rhythm of 6, 4, and a grouping into 5-place numbers, to
l repetition from the beginning, after each exposure, which
had just used with the consonants.
ıdividual differences in processes between the reagents who
not change their methods radically were: Mn. recalled from
tory imagery of 4-place numbers. Rt. used a kinaesthetic
hm for six digits, and visual imagery for the last four. Sl.
ed in pairs, 2-place numbers, and recalled the last figure
wo visually. Ly. used associations furnished by perceiving
tions between the numbers, their sums and differences, re-
ed the numbers expressing the relationships visually, and
lled the numbers themselves from auditory imagery
orted by the association-meanings.
ıitial capacity ranged from .37 to .92 points, per series,
classifies the reagents into four groups: .8, .6, .5, .4.
nprovement in per cent of increase over initial efficiency,
the reagents who did not radically change their methods, was:

	Regular	1st Control	2d Control
Group 1.	Mn. 17 Rt. -7*		
Group 2.	Sl. 30		
Group 3.	Ly. 15		

*This score illustrates the inadequacy of the Spearman "Footrule for scoring the memory test;" (*vid.* Whipple: Tests, p. 367). The loss was caused by four reproduced numerals in correct order being misplaced; omitting this score, the reagent shows a gain of 12%.

These reagents presumably improved somewhat by reason of their training, the results comparing favorably with those of corresponding groups in the preceding test, but since there are no control averages to compare with them, the supposition rests unproven.

Those who changed methods, with one exception gained more: Group 1. Cr. 10%, He.-2%; Tn. 16.7%; Group 2. Wf. 52%, Ms. 33%; Group 3. Ds. 11%; Group 4. Le. 17%, Al. 70%.

(11) *Memory of Visual Signs*

The signs (see p. 79, and Appendix B. Fig. 11, p. 291) were so unfamiliar that, although they were clearly perceived in the one-second exposures, they were not apperceived and therefore were not usually subject to recall. However, some of the signs suggested to the reagents familiar things or conventional characters, and in this way made an impression that could be utilized for recall. This impression did not need to be largely visual, as the test presupposed, but could be converted into any other imagery that would serve as a carrier for the suggested thing, plus a modicum of visual or other imagery which suggested any necessary variation in the drawing. Thus, none of the reagents reproduced more than the last sign from purely visual memory; but gave the symbols names of the things they resembled, as, d, J, 8, 10, omega, phi, dutch cap, etc., and approximated the signs in their reproductions through retention of these names, principally in verbal imagery, and secondary criteria of deviation from the outline of the conventional thing.

The test shows the impossibility of forcing the use of visual imagery by such material and method.[104]

(12) *Memory of Associated Pairs*

Memory for "paired associates" is a variation of Müller and Pilzecker's[1] "Treffermethode," and has been used with vocabulary material (Bourdon,[2] Thorndike[3]). Our method (see p. 79; also Appendix B, Fig. 10, p. 290), differs from the original in the simultaneous presentation of the pairs to be associated. A printed consonant and a printed digit were presented together in series of 10; recall of the digit was required upon a second presentation of its associated consonant.

The process was intended to be memory of contiguous associations, but since this was more difficult or unfamiliar than memory of serial order, the latter was not always inhibited, and introspections are not sufficiently full to be trustworthy in reporting this source of error.

Processes, so far as introspections indicate them, varied greatly: The usual process was to name the letter and digit together so as to get a strong unitary kinaesthetic, auditory, or kinaesthetic-auditory, image of the pair; and when the letter appeared alone it was again named to recall its associate. It is a simple process, and if the reagents had been so instructed they probably could have adhered closely to it without great variation. But variation appears immediately in the 'aufgabe,' and introspections scarcely more than indicate that it occurred.

Mn. said the numeral came as an unfinished syllable of a word.

Mn., Le. and others found that familiar or significant letters held their associations best.

He. and Ms. found visual (G6, C5) and other associations: H2 from chemistry; C3 from alphabetic order, etc.

Rt. and Ly. supplemented kinaesthetic imagery with visual, and found some combinations easier to pronounce.

Mn. and Ly. were caused some distraction by having to inhibit a tendency to notice serial order.

[1] Müller und Pilzecker: Experimentelle Beiträge zur Lehre vom Gedächtniss. Zeits. f. Psych. Erg. 1900. 1:2.

[2] Bourdon: Recherches sur l'habitude. Année Psych. 1901. 8:327ff.

[3] Thorndike: Memory for paired associates. Psych. Rev. 1908. 15:122ff.

[104] *Cf.* Kuhlmann: On the analysis of the memory consciousness; a study in the mental imagery and memory of meaningless visual forms. Psych. Rev., 1906, 13:316ff.

He. found that some associates not repeated came up for recording. The attitude of the reagents toward these indefinite associations varied somewhat in the two tests and would be a source of error in the results. This attitude is indicated by the relative number of recorded associations that proved correct:

Per cent, of the numbers recorded, that were correct.

	First	Final
Mn.	39	43
Le.	56	83
Rt.	56	42
Sl.	54	41
Ly.	56	56
He.	91	80
Cr.	30	50
Al.	50	16
Ms.	31	66
Wf.	93	66
Es.	52	94
Pe.	42	46

Results show that there was a general tendency for associates of earlier series to persist and cause errors, especially if they were intensified by significant letters or by mnemonic connections.

The initial capacities ranged from .08 to .42 points and results are so irregular as to make their inspection unprofitable.

(13) *Learning 12-Letter-Rectangles*

Memory for consonants, simultaneously presented in a "letter-square" under conditions of number of letters and time of presentation that preclude a perfect score, has been used for two principal purposes: (1) to study the mental imagery (Binet et Henri,[1] Toulouse,[2] Cohn,[3] Segal,[4]); and (2) to test mental ability (Binet,[5] Sharp,[6] Winch[7]). The test is standardized for the former purpose by Titchener[8]; for the latter by Whipple.[9] It has also been used for the study of the relation of attention to memory (Smith[10]). The letter-square, or, more precisely, the letter-rectangle usually contains 12 letters in three horizontal rows, and is presented from 10 to 20 seconds. Our test (see p. 80) is similar to Whipple's and follows Cohn, Smith, and Segal: 12-consonant-rectangles exposed 10"; reproduction after a free interval of 10".

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[1] Binet et Henri: La psychologie individuelle. Année Psych. 1895. 2:436ff.

[2] Toulouse: Enquête medico-psychologique sur les rapports de la supériorité intellectuelle avec la névropathie. (Zola). 1896. P. 182.

[3] Cohn: Experimentelle Untersuchungen über das Zusammenwirken des akustisch-motorischen und des visuellen Gedächtnisses. Zeits. f. Psych. 1897. 15:162.

[4] Segal: Ueber den Reproductionstypus und das Reproduzieren von Vorstellungen. Archiv f. d. ges. Psych. 1908. 12:133ff.

is a fairly simple exercise, like most of the other standard
l Tests," yet it, too, may evoke quite different processes
various reagents, and may become several different tasks
the same individual.

effect of practice on the processes involved was described
ages back (pp. 94ff.), in the discussion of training re-
Here we have to do with fairly initial abilities, except
final tests of Rt. and Sl., who trained on this work, in
variability shows itself freely.

reagents attempted the task by:

Reading in vertical columns of 3 letters.

Reading in lines of four letters (the general method).

1) Rote repetition, over and over, for kinaesthetic-auditory impression.
2) Fewer repetitions, apperceptive; grouping of letters, rhythm.
3) Visual impression; intensified or casual.
4) Associating letters.[105]
    a) by sound, rhyme.
    b) by form (e.g., VWYM, CGQ).
    c) by alphabetic position (BC, KL, XZ).
    d) by signification; favorite form, initials, abbreviations, words, etc. (DV, deo volente; SFTR, San Francisco Teddie Roosevelt, or sifter).

: Attention et adaptation. Année Psych. 1899. 6:324ff.
p: Individual psychology: A study in psychological method. Am. Jr. 1899. 10:353.
h: Immediate memory in school children. I. Visual. Br. Jr. Psych. :128.
ener: Experimental psychology. 1901. Vol. I. Part II. Instructor's 396ff.
ple: Manual of mental and physical tests. 1910. Test 38, B. 368.
h: Relation of attention to memory. Mind. 1895. N.S. 4:47ff.

advantage of logical connections, *vid.* Balaban: Zeits. f. Psych. 56: 379-400. For agreement of these results with others, *vid.* Smith: . 57; Cohn: *op. cit.* pp. 178ff.; Segal: *op. cit.* S. 160; and Michotte et (Contribution a l'étude de la mémoire logique. Études de Psychol. :72-81). Calkins (Psych. Rev. 5:460) found the tendency to combine d concrete words in four-fifths of her 52 reagents; three-tenths of ds, chosen to prevent natural combinations, were forced through into some sort of relation.

To illustrate:

P H Q K D S T N L G R F	(a) Continuous repetition of the first line and the first column, on the accompanying 12-letter-rectangle, yielded 15 points (Le.); or of the first two lines, 22 points (Rt.). (b) Repetition of letters in lines, by pairs, yielded 20 points (Le.). (c) Repetition of the first two lines; visual image of the last line on the forehead, gave 24 points (Sl.). (d) Wholly representative (**Phone quick**, long distance, **lograft**) gave 36 points, a perfect score (Cr.).

Clearly those four methods involve different kinds of work, besides yielding different scores.

Reproduction was usually in combined imagery; the more common being, kinaesthetic-auditory, but often also auditory, visual, and representative (associations), upon the same letters. Then different letters were sometimes assigned to the different forms of imagery so that their coöperation yielded more letters than could be reprodued by combining on the same letters. Sometimes only the imagery representative of the letters was prominent; *i.e.*, but little imagery of the letters, when associations for them were used.

Some of the reagents made radical changes in their methods in the final tests: Mn., Cr., Ms., and Bt., changed to much greater use of associations; Le. from more rapid repetition, over and over, to a single apperceptive repetition and the use of associations.

Other reagents retained their old methods:

Rt., who trained on this work, repeated the first six letters for reproduction from kinaesthetic imagery; the next two letters were assigned to a visual association, or were reinforced for a visual recall, and the last line casually observed for visual recall to be recorded first while retaining the more vivid imagery to be recorded later.

Sl., who also trained on this work, repeated the first two lines for kinaesthetic recall, and fixed the last line by associations, with meaning, or by visual imagery, which was very unstable.

He., Ly., and Wf. made forming associations a method.

Al. sought to get a kinaesthetic-auditory impression of the whole card.

Initial efficiency ranged from 15.5 to 27.3 points, classifying the reagents into four groups: 27, 22, 18, 16.

Improvement upon initial efficiency, for the reagents whose methods remained practically the same, was:

	Regular	1st Control	2d Control
Group 1.	He. 7		
Group 2.	Ly. 26	Wf. 8	
Group 3.	Sl. 45 Rt. 44 Al. 4		
Group 4.			Ed. 12.3

Ly.'s is the only score that invites speculation. Her method was to form associations, and her improvement is due to doubling her facility in forming them; this differs greatly from improvement in vivifying impression and heightening the power of recall of imagery, which contributed to the improvement of Rt. and Sl., and seems in no way to depend upon her training in simple reaction. In her method variability is greater than might at first be supposed: In the final test, although the material presented was the same as that of the first test, (a) different letters were chosen for the associations, and (b) when the same letters were chosen the associations were sometimes different (DZ dizzy, Diaz; WSH wash, Washington). Facility in forming associations varied greatly, irrespective of material, even within the same test; *e.g.*, in the first test, Ly. began with forming associations as a method, and by the fourth experiment had made a perfect score by holding all the letters in associations, but when the 7th card, used in the above illustration, was exposed, she could find no associations for the letters and was reduced to repeating them in pairs, making a score of 10 points, (half her average). In her first test 48% of her recorded letters were held in associations, in her final, 90% were so held.

Change in method was advantageous (improvements being: Group 2. Cr. 26%; Group 3. Mn. 64%, Bt. 27%; Group 4. Ms. 48%, Le. 14%), sometimes more than any other circumstance; as is well illustrated in the case of Ms., a control reagent, who, although her initial ability was but a little below theirs,

showed greater improvement than was made by either of the two reagents who trained on this work 18 days.

An interesting effect of the training on this work is found in the results of Rt. and Sl., in comparison with the results of others, obtained on additional experiments in this test, three in which numerals were exposed, and one in which commercial signs were exposed: These reagents carried over their method, as recorded above, to the numerals, changing from 4-place and 2-place grouping, respectively, and made 83% and 70% improvement (while the other reagents ranged from loss to 55% improvement), and this improvement is greater than was made with the consonants upon which they trained. To the commercial signs, the method was absolutely unfitted, and they alone lost in the scores of the final test .(Rt. 7%, Sl. 17%), Sl., whose method was the more mechanical, losing the most.[106]

The chief factors of improvement in this test were:

(a) More adequate method.

(b) Better coördination of the kinaesthetic, auditory, and visual modes of imagery, and assigning them to different material rather than permitting them to merely support each other in making vivid a smaller number of letters.

(c) Better impression and recall through each kind of imagery.

(d) More use of associations.

(e) Associations more apperceptive.

(14.) *Same. With Distraction*

Distraction in learning consonants visually presented in letter-rectangles has usually been applied to the period of perception (Smith,[1] Cohn,[2] Segal[3]) and has consisted in counting, adding, or intoning a vowel sound; occasionally the distraction has been applied to the interval between perception and reproduction (Bingham,[4] Finzi[5]). In our test (see p. 80) the reagent was required to add digits pronounced by the experimenter during the interval between perception and reproduction, and to write down the sum before he began recording his letters.

[1] Smith: *op. cit.*, 47ff.
[2] Cohn: *op. cit.*, 162.
[3] Segal: *op. cit.*, 133.
[4] Bingham: Memory, II. Psych. Rev., 1894, 1:453ff.
[5] Finzi: Zur Untersuchung der Auffassungsfähigkeit und Merkfähigkeit. Psych. Arbeiten, 1899-1901, 3:295.

[106] *Cf.* Sleight, *op. cit.*, pp. 440, *et seq.*

Interpolation of processes, as usual, again increases variability in processes and results.

In the preceding test attention could be given, during the 10-second interval between impression and recording, to the retention and fixing of the letters; in this, a variable division of the attention takes place between retention and adding, resulting in a further important source of variation beyond those of the preceding test.

(a) The adding may be carried on either in visual imagery, or auditory imagery, partial sums being kinaesthetically imaged or repeated, while the attention shifts quickly[107] to the verbal or other imagery from which the recall of the letters is sought to be made.

(b) The whole attention may be given to the adding in the interval while the numbers are pronounced.

(c) Or, attention may be given to further fixing the imagery of the letters for surer recall, and turn with leisure and confidence to the auditory images of the numbers after they have all been pronounced.

The first method is apt to lead to incorrect sums and to great decrease in the score; the second to correct sums, but to decrease in the score; the third to correct sums, if auditory imagery is fair, and to a good score.

Variability is further increased by the varying degrees of conflict between the part-processes. Difficulty in adding, using the first method above, dispersed clear imagery, because of confusion of mind it occasioned (Le.). Both kinaesthetic and visual imagery were interfered with, when the second method was used (Rt.). Associations escaped when they were merely verbal, because of the conflict with kinaesthetic impressions in pronouncing the partial sums (Ly. He.).

Since recall is surer from associations than from imagery of the letters,[108] almost all reagents resorted to them, but with

[107] Smith (Mind. N.S. 4:66) found that the attention of his reagents, who were set to learning the letters while adding, oscillated between the two tasks.

[108] In the preceding experiment, when letters had been fixed in an association, no further attention was given to them, the interval being filled with

varying facility. Not only the readiness to form associations was variable, but selection of such kinds of associations as involve more apperception was variable, and, consequently, retention of associations was variable.

The whole association may be lost; or by a slight cue may yield its quota to the score. The following will illustrate how near a 0 score is to a score of 100%, when associations are used: A reagent gave full attention to adding during the interval, recorded a correct sum, and found that he could not recall a trace of his associations or even a letter; after a moment, weak kinaesthetic imagery brought back the association of the first two letters; then in recording these, associative connections grew stronger and the associations all returned (led by meaning rather than by verbal imagery), and a perfect score was produced (Cr.).

An association may be recalled, however, and be either untrustworthy or useless, because of the absence of further imagery relating the letters definitely to it. The influence of the imagery is seen in the record of VNWY from the associated word "Vanity"; **Van(it)y**; the substitution of "W" for "it" was held in visual imagery (Cr.). The adding was often fatal to this imagery as may be seen from the failure of "North Buckham" to produce NRT BKYM by producing NTH, thus yielding the lowest score of the series (Cr.).

None of the reagents were constant in their methods, and initial ability ranged from 8.3 points to 19.5. Distraction ranged from 15% to 60%.

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effort to retain by repeating letters held in less sure imagery. At the beginning of the first test, here, the reagent said: "I rested my attention on the last column more than on any other, but the second seemed to form a word; I retained the latter and could not remember the former." (Mn.). This conforms with the findings of Balaban (*op. cit.*) that associative learning was eight times more effective than mechanical memorization, and of Arnold (The initial tendency in ideal revival. Am. Jr. Psych., 1907, 18:251) that recall is insured by a more closely organized disposition, a better developed meaning, a more complete organic whole.

(15) *Word-Completion*

This test (see p. 80f.) is an application of Ebbinghaus'[1] "Completion Test" to words, and differs from Whipple's[2] "Word-building" test in greatly limiting the possible combinations. It involves equivocal reproduction or controlled association, and was designed to measure a narrow type of inventive or imaginative power.

Some of the reagents completed the list in less than 100 seconds; others left it unfinished in 300. The process differed greatly, especially with respect to the 'Aufgabe.' All reagents sounded the consonants phonetically, interpolating between them indefinite vowel sounds, until a word was called up by the kinaesthetic-auditory cue. Upon a hitch in getting a word, some of the reagents (Le., Rt., Cr., Ms., Wf.) started systematically sounding definitely the various vowels, taking them in order, between the first pair of consonants. Only once did the visual form suggest a word (Rt.).

Although instructions were clearly given to add letters anywhere to complete a word, only twice did an added letter precede the first consonant (Ly., Ms.), and occasionally the reagents otherwise limited their task, *e.g.*, Le. and Ms., after their experience in the first test, limited additions in the final test to the two spaces between consonants, and failed to complete the ten words within the 5-minute time-limit; He., in his first test, limited himself in the first few words to the space between the first pair of consonants, and after leaving an incomplete word and properly assigning himself to other spaces in completing following words, he returned to it, again limiting himself as before.

Since the difficulty of the task depends upon the 'Aufgabe,' which the reagent holds in his mind, it is obvious that quantitative results, without adequate introspection, are without value. Even with adequate introspection, there is no way to equate results when the processes are greatly different.

The test is of value in showing how, under precisely the same

[1] Ebbinghaus: Ueber eine neue Methode zur Prüfung geistiger Fähigkeiten und ihre Anwendung bei Schulkindern. Zeits. f. Psych., 1897, 13:401ff.; also Whipple's Test 48, p. 445ff.
[2] Whipple: Manual of mental and physical tests, 1910, Test 27, pp. 441ff.

instructions and external conditions, different reagents vary widely (a) in the task to be performed, and (b) in the processes they use to carry out a similar task.

(16) *Trains of Ideas*

The mental processes involved in free reproduction or uncontrolled association made early contribution to experimental psychology. They furnished Galton,[1] as he walked along Pall Mall and noted the ideas that came into his mind as he scrutinized successive objects that caught his eyes, material which he learned to subject to measurement. They are, of course, employed for mental diagnosis in the famous "word-association" test; and they have been employed in unbroken series of from 10 to 100 words[2] for the study of association (Cattell and Bryant[3]), of effect of immediate environment upon association (Flournoy[4]), of community of ideas of men and women (Jastrow,[5] [7] Nevers,[6] Calkins,[8] Tanner,[9]), of individual differences in mental processes (Secor,[10] Binet[11]); but they have also been used in unbroken series for determining rate of mental activity (Wissler,[12] Thompson,[13] Brown[14]). In our test (see p. 81) 2-minute series were written after the stimulus words: "horse," "potato," "flute."

Since most of the individual scores run up to about the maximum speed in writing, it may be presumed that in this test, when the ideas are recorded by the reagent, reproduction is seriously limited by recording. Even were the phrases and

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[1] Galton: Psychometric experiments. Brain. 1879-1800. 2:151.

[2] *Vid.* Whipple: Manual of mental and physical tests. 1910. Test 33, pp. 313ff.

[3] Cattell and Bryant: Mental association investigated by experiment. Mind. 1889. 14:230ff.

[4] Flournoy: De l'action du milieu sur l'idéation. Année Psych. 1894. 1:180ff.

[5] Jastrow: A study in mental statistics. New Review. 1891. 5:559ff.

[6] Nevers: Dr. Jastrow on community of ideas of men and women. Psych. Rev. 1895. 2:363ff.

[7] Jastrow: Community of ideas of men and women. Psych. Rev. 1896. 3:68ff.

[8] Calkins: Community of ideas of men and women. Psych. Rev. 1896. 3:426ff.

[9] Tanner: The community of ideas of men and women. Psych. Rev. 1896. 3:548ff.

[10] Secor: Visual reading: A study in mental imagery. Am. Jr. Psych. 1899-1900. 11:225ff.

[11] Binet: L'Étude expérimentale de l'intelligence. 1903. P. 309.

[12] Wissler: Correlation of mental and physical tests. Psych. Rev. Mon. 1901. 3: No. 6, p. 8.

[13] Thompson: Psychological norms in men and women. Univ. Chicago Contrib. to Phil. 1903. Pp. 100ff.

[14] Brown: Some experimental results in correlation of mental abilities. Br. Jr. Psych. 1910. 3:306.

words spoken, the process would be similarly limited in speed. Scores, therefore, do not so much show rapidity of reproduction as rapidity of expression and regularity of reproduction. And since the whole field of the reagent's experience is available for reproduction, with all the grades of liability for recall, variation in regularity is inevitable; nor does it seem that variable attention rather than direction of 'leads' into various fields of experience is the greater cause of variation.

Initial efficiency ranged from 55 to 100 ideas for the six minutes.

Qualitatively, some interesting facts were presented:

(a) The 'Aufgabe' was not the same for all reagents, although instructions and external conditions of the experiment were uniform. The usual method was to begin with the idea suggested by the stimulus-word and follow the course suggested by the last word until new 'leads' would develop from some prominent member of the last series, or 'story,' thus introducing a new 'story,' etc. But Sl. bound himself to record only ideas related directly to the stimulus-word, and gave second place to the suggestion of recorded ideas; and Wf. followed an intermediate course approaching closely Sl.'s method.

(b) Most of the reagents find that of the flood of memories and images only a few, usually the most prominent, can be recorded.

(c) The 'stories' from which the constellations of ideas are chosen for recording are related to various periods of the reagent's experience and tend to fall upon the same periods of experience, for all stimulus-words given in one sitting, but upon different periods for the same stimulus-word given upon different days. This merely indicates 1) the organization of experience, in cross-section; and 2) the flux of experience, in longitudinal-section. Ms. in her first test drew mainly upon experience of her childhood; in her final test, upon those of recent years and days.

(d) The remote and recent experiences are sometimes drawn upon in the same minute, due to the prominence of identical factors in their memories; emotional or cognitive.

(e) Anxiety about one's work, or great interest in an event, leads all trains of ideas to that center of interest, even when approaches are repeatedly inhibited (Cr., Le.). This shows how efficient the selective influences are, in the control of the central elements of consciousness. Monomania would seem to be but an exaggeration of this natural process. In this case the control seems to be given over to the emotional set of consciousness.[109]

(17) *Extensive Threshold of Visual Attention. Free*

The number of letters that can be apprehended in a momentary exposure of a rectangle containing from 6 to 12 letters has been thought to constitute a measure of the "extensive threshold of attention" (Wundt[1]) or the number of elements that can be simultaneously grasped by consciousness. The time of presentation is usually about 0.1 seconds, less than the eye-reaction time, in order to limit apprehension to a single fixation of vision; but owing to the persistence of the after-image for about 0.25 seconds (Schumann,[2] Hylan,[3] Messmer[3a]) and to the visual memory after-image that may appear a few seconds later (Schumann[2]), the attention may fluctuate successively over the elements so held, thus augmenting unduly the measure of the threshold of attention and relating it to the 'memory-span' for successively presented letters. Wundt[1] warns the reagent to avoid this error through introspectively distinguishing between the simultaneous and the successive activities. The test has been used to measure visual perception and attention (Griffing[4]) or the range of visual attention (Whipple[5]). In our test 12-consonant-rectangles were presented for about 0.1 sec. (85 sigma); reproduction was required after a free interval of 5 seconds (see p. 81).

[1] Wundt: Grundriss der Psychologie. 10te Auf. 1911. Sec. 15, Par. 6 (pp. 254ff.); also Grundzüge der Physiologischen Psychologie. 5te Auf. 1902. III:351ff.
[2] Schumann: Die Erkennung von Buchstaben und Worten bei momentaren Beleuchtung. Bericht u.d. I. Kongress f. Exp. Psych. 1904. 34-40; *also* Psychologie des Lesens. Bericht u.d. II. Kongress f. Exp. Psych. 1906. S. 174.
[3] Hylan: The distribution of the attention. Psych. Rev. 1903. 10:373. 498.
[3a] Messmer: Zur Psychologie des Lesens bei Kindern und Erwachsenen. Archiv f. d. ges. Psych. 1903-4, Bd. 2, S. 206.
[4] Griffing: On the development of visual perception and attention. Am. Jr. Psych. 1895. 7:277ff.
[5] Whipple: Effect of practice upon range of visual attention and of visual apprehension. Jr. Ed. Psych. 1910. 1:249ff.

[109] This test furnishes a good diagnosis of the reagent's experience at the time it is taken. Repeated tests would make it quite possible to characterize the reagent's mental life. A person could not in a briefer or more efficient way keep a diary of his real interests than by this two-minute test, accompanied by a commentary.

nalysis of processes involved in the work of this test was
e under the head of Training Results, some pages back
82ff.); only a general indication of the fact of variability
rocesses, therefore, need be made here.

) The field of the attention may vary from the whole card
line or to a few spaces. In the first case, vague imagery
es up the bulk of the material dealt with; in the second,
clear and vague are entertained; in the third, only clear
gery.

) The type of imagery may determine the process: If the
al impression is immediately converted into kinaesthetic or
esthetic-auditory imagery, reproduction is largely limited to
rs clearly seen; if the visual impression is held for a while,
re being converted, more dimly seen letters become fixed.

) If the attitude toward vague imagery is encouraging,
e unrecognizable imagery 'matures' into letters, the record
hich the score often justifies.

) If, in recall, disparate imagery supplements itself on sepa-
letters, more letters are recorded.

) Some distraction seemed peculiar to the test: Readiness
he naming process was not at times satisfactory because
ow reproductivity of the letter-names; to some reagents
e combinations of letters were retarding because of the non-
onious pronunciation of their names; to some, special letters
nificant or disagreeable) retarded the process; several times
sures were completely missed by winking.

trospections show that the process varied with each reagent
ach test, and sometimes considerably between tests.

here was a general effort to convert the visual impression
isual imagery into kinaesthetic imagery or impression (in-
nt pronunciation); this conversion reduces reproduction to
te' process, which doubtless is the line of least resistance
emorizing. Introspection says: "First the imagery is very
se, visual, which I convert into kinaesthetic (verbal); then
peat rapidly, almost as one word, and this is accompanied
veak visual imagery. Then I seem to feel sure of the
rs—they seem to lie on my tongue and are less full of
ning than at first" (Rt.). "After repeating letters I felt
dent that I had them; they would not fly away" (Wf.).

In practice, the moment of this conversion was adjusted by the necessity of fixing many distinct impressions before they got away, and the necessity of permitting them to mature more clearly in order to be either cognized or held in visual imagery in sufficiently stable form to remain while fixing others by naming. The shifting of this moment was necessitated by the varying grades of clearness of the imagery, and inexpert shifting was fatal to the score. Better coördination of processes here resulted through practice, and variation in methods as indicated above must be credited with considerable variation between individual reagents, resultant upon this particular practice effect.

Initial capacities varied in average scores from 4.1 to 9.1 points (3 points to a correctly placed letter), and divide the reagents into four groups: 9, 8, 6, 5.

Improvement in per cent upon initial capacity, for the reagents who retained in their final tests their old methods, was:

	Regular		1st Control		2d Control	
Group 1.	He.	12				
Group 2.	Le.	58	Wf.	21	Ty.	4
	Rt.	10				
Group 3.	Al.	45				
	Cr.	42				
Group 4.	Sl.	25				
	Ly.	14				

Al. differed from the other reagents in attending consistently to the whole card.

Three reagents made radical changes in their processes in the final test: Mn., who trained 18 days on this work; and Ms. a control reagent, changed from attending to the whole card to attending to limited parts of it, usually the first line. Dn. changed from intentionally varied methods in the first test, involving attending to the whole card, limiting the field in various ways, and closing one eye and then the other to see if a clearer impression could not be obtained, to a regular method of restricting the field and of binocular vision. These changes were advantageous: Group 4. Mn. 147%, Ms. 47%; Group 5. Dn. 39%.

That great difference in the score results from variation in the extent of the field attended to, is illustrated by individual scores made by Ms. in her first test. In the first six experiments, with attention upon the whole card, she made no score above 4 points; in the last four experiments, with the field restricted to the upper right-hand corner, she made no score below 8 points. Mn.'s great gain is based upon those six experiments, for the averages of the scores of the last four experiments in her first test is higher than the average of either the last four or all of the experiments of her final test.

The results of this test offer several anomalies which indicate the futility of merely quantitative treatment of work of this kind. Ms., a control reagent, shows greater gain than does Al., who trained on this work for 8 days; besides (a) the difference in capacity, indicative of difference in kind of work, (b) the gain is exaggerated by the per cent being reckoned upon lower initial capacity. Wf., a control reagent, shows a greater per cent of gain than He.; although their initial capacities are not so unlike, this excess of gain is illusory, since in absolute gain He. excells, and from He.'s greater initial capacity, it is conceivable, improvement is more difficult to make.

Cr. and possibly He. are the only reagents who appear to have brought to the test any advantage from their training; both improved more than the other reagents who did not train in this work, in regular performance indicative of more constant conditions of attention.

(18) *Same. With Distraction*

Adding four digits during an interval of 5 seconds between perception and recording is a doubtful distraction, ranging from 0 to 59%. It was but negligible for Mn. in both tests; for Sl., Ly., and Dn. in the first test, and for He. and Al. in the final test; and it varied between the two tests considerably for all the reagents except Mn., Cr., and Ty.

The chief cause of variation in the scores (initial capacity ranged from 3.2 to 6.9 points, and final capacity from 2.8 to 11.4 points) was the conflict between the visual or kinaesthetic-

auditory imagery in which the letters were being held and the kinaesthetic imagery of the partial sums in adding. Where distraction was overcome, the usual method was to quickly name the letters and thus fix them in kinaesthetic imagery, and add the numerals at leisure from auditory images after they had all been pronounced.

(19) *Tapping*

Tapping as rapidly as possible during an interval of from 5 seconds to 2 minutes, with a pencil, stilus, or telegraph key, has served as a test for voluntary motor ability and, with the longer intervals, for fatigue (Bryan,[1] Dresslar,[2] Gilbert,[3] Moore,[4] Binet et Vaschide,[5] Kirkpatrick,[6] Bagley,[7] Bolton,[8] Kelly,[9] Thompson,[10] Burt,[11] Wells[12]), and has been standardized by Wells[13] and Whipple.[14] Our test follows Wells: 5 series of 30", with 25' rests. (*Vid.* p. 81f.).

Maximum rate of voluntary activity as expressed in tapping on a Morse key (adjusted as preferred by telegraph operators—1 mm. amplitude, 50-gram tension) seems a very simple process. But our results show it to be variable and to depend upon other important factors besides attention and fatigue.

Results gave the "Total Efficiency" (average number of taps

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[1] Bryan: On the development of voluntary motor ability. Am. Jr. Psych. 1892. 5:123ff.

[2] Dresslar: Some influences which affect rapidity of voluntary movements. Am. Jr. Psych. 1892. 4:514ff.

[3] Gilbert: Researches on the mental and physical development of school-children. Studies from Yale Psych. Lab. 1894. 2:48.

[4] Moore: Studies of fatigue. Studies from Yale Psych. Lab. 1895. 3:92ff.

[5] Binet et Vaschide: Expériences de vitesse chez les jeunes gens. Année Psych. 1897. 4:200ff; also Épreuves de vitesse chez les jeunes garçons. *ibid*. 64ff.

[6] Kirkpatrick: Individual tests of school children. Psych. Rev. 1900. 7:274ff.

[7] Bagley: On the correlation of mental and motor ability in school children. Am. Jr. Psych. 1900-1. 12:195ff.

[8] Bolton: Relation of motor power to intelligence. Am. Jr. Psych. 1903. 14:354.

[9] Kelly: Psychophysical tests of normal and abnormal children; a comparative study. Psych. Rev. 1903. 10:345ff.

[10] Thompson: Psychological norms in men and women. Univ. Chicago Contrib. to Phil. 1903. 4: No. 1. 12ff.

[11] Burt: Experimental tests of general intelligence. Br. Jr. Psych. 1909. 3.132.

[12] Wells: A neglected measure of fatigue. Am. Jr. Psych. 1908. 19:345ff.

[13] Wells: Normal performance in the tapping test. *ibid*. 347-483.

[14] Whipple: Manual of mental and physical tests. 1910. Test 10, pp. 100ff.

series of 30 seconds), and the "Fatigue Index" (found by ding the average of the last five intervals of 5 seconds ı, of the first series, by the number of taps in the first rval of 5 seconds).

he manner of tapping varied between the different reagents, ı respect to the parts of the arm, forearm, wrist, hand, fingers, put in vibration, with respect to the amplitude vibration, the manner of grasping the key, the amount of rvation and bodily tension, determination to resist fatigue, accompanying psychial processes, such as counting the taps groups. And it varied, in a less degree, in an individual gent's work.

Total Efficiency" ranged from 176.8 to 245.8, in the first , and reagents fall into five groups: 246, 218, 205, 198, 180. hange in per cent of initial capacity, was as follows:

	Regular	1st Control	2d Control
Group 1.	Rt. -1.5		
Group 2.	He. 5.0		
Group 3.	Sl. 3.2	Ms. -1.3	
	Cr. 3.2		
	Le. -0.2		
	Ly. -2.6		
	Mn. -3.3		
Group 4.		Wf. -1.2	
Group 5.			Me. 0.6
			Wx. 1.2

he changes in the table may indicate changes in fatigue, e objective fatigue is said to increase the time,[110] and the is recommended as a measure of fatigue;[111] they may indi- changes in the capacity of attention which opposes fatigue; hey may be due to both these causes as modified by others. hat the last conjecture is sometimes true is shown by the ılts of Rt., Le., and Sl. Rt.'s practice curves of the two s are precisely the converse of each other; his first curve ws great practice-effect in the second series, reaching a ximum in the third series; his final curve begins with nomenal speed (267), loses greatly in the second series,

Moore: Yale Studies, 3:95.
Wells: Am. Jr. Psych., 19:344.

reaching minimum in the third series. Le.'s curves are similar but show less practice-effect and loss. Sl.'s final 'fatigue curve' is inverted, differing from all others in showing marked practice-effect up to the fourth interval. Unfortunately, introspections are not sufficiently full to indicate the causes of these variations.

Usually the two practice curves of a reagent are similar: Both show practice-effect in the cases of five reagents (Mn., Sl., Cr., Ms., Wx.); no practice-effect in the case of four reagents (Le., Ly., He., Wf.); and loss in the case of one reagent (Me.).

Susceptibility to fatigue, as is inversely indicated by the "Fatigue Index" (see p. 82), ranged from 87 to 97, placing the reagents into three groups: 95, 90, 85. Complete resistance to fatigue would be 100.

Per cent of change in resistance to fatigue was:

	Regular	1st Control	2d Control
Group 1.	Sl. 18.5	Ms. -5.1	Wx. -1.9
	Le. -9.5	Wf. -11.7	
Group 2.	Ly. 5.6		Me. -1.0
	Cr. 1.1		
	He. -4.4		
	Rt. -5.4		
Group 3.	Mn. -3.5		

The agreement between the two tables showing the "state" of fatigue and the "susceptibility" to fatigue in the cases of Mn., Le., Rt., Sl., Cr., Ms., and Wf. indicates a reliability for the test as a measure of fatigue which is supported, in part at least, by the fact that the final tests were taken at the end of the school-year when most of the reagents could be expected to be working under greater fatigue than when the first tests were taken.

But there are disturbing influences: He. gained 5% in "Total Efficiency" and lost 4.4% in resistance to fatigue; Ly. lost 2.6% in "Total Efficiency" and gained 5.6% in resistance to fatigue; Sl. gains in both, but made in his final test the remarkable "Fatigue Index" of 115, which is supported by his remarkable 'fatigue curve' drawn from the averages of the respective intervals in all series of the final test, which shows a marked practice-effect.

No relation between the results of this test and the training or improvement in attention is evident.

f. Extent of Variability

In the preceding analyses of processes it was shown (a) that in almost every test individual reagents differed from each other, often greatly, in the way in which they performed the work of the test;[112] and (b) that it is the rule for the individual

[112] That individual variation in kind of mental work performed, when reagents set themselves to the same objective task, is not peculiar to the material or the method of our tests, may be seen by inspecting any report of investigation in which the mental processes of the different reagents are subjected to analysis. The contributions to individual psychology and the studies of "imagery type," as has already been noted (foot-note to p. 69), reveal this qualitative variability in every class of mental activity. To select a few typical references for further explication, it is shown specifically in discrimination of clangs (Whipple: An analytical study of the memory image and the process of judgment in the discrimination of clangs and tones. Am. Jr. Psych. 1901. 12:425-433, 448-452); in memory for sounds of familiar things, presented by a graphophone (Kuhlmann: On the analysis of auditory memory consciousness. Am. Jr. Psych. 1909. 20:194ff), in memory for meaningless visual forms (Kuhlmann: On the analysis of the memory consciousness. Psych. Rev. 1906. 13:316ff), in memory for nonsense-syllables (Müller und Schumann: Experimentelle Beiträge zur Untersuchung des Gedächtnisses. Zeits. f. Psych. 1894. 6:303-5; Pentschew: Untersuchungen zur Ökonomie und Technik des Lernens. Archiv f. d. ges. Psych. 1903. 1:417ff; Ebert und Meumann: Ueber einige Grundfragen der Psychologie der Uebungsphänomene im Bereiche des Gedächtnisses. Archiv f. d. ges. Psych. 1904. 4:1ff; von Sybel: Ueber das Zusammenwirken verschiedener Sinnesgebiete bei Gedächtnisleistungen. Zeits. f. Psych. 1909. 53:327ff), in memory for various material (Bingham: Memory. Psych. Rev. 1894 1:461ff; Whitehead: A study in visual and aural processes. Psych. Rev. 1896. 3:258ff; Gamble: Study in memorizing various materials by the reconstruction method. Psych. Rev. Mon. 1909. No. 43); in word-association (Galton: Psychometric experiments. Brain. 1879-80. 2:158; Calkins: Short studies in memory and in association. Psych. Rev. 1898. 5:460; Mayer und Orth: Zur qualitativen Untersuchung der Association. Zeits. f. Psych. 1901. 26: 1-13; Wreschner: Die reproduktion and Assoziation von Vorstellungen. Zeits. f. Psych. Erg. Bd. 3. 1907, S. 86ff; Koffka: Ueber Vorstellungen. 1911); in imagery of things (Philippe: Un recensement d'images mentales. Rev. Philos. 1897. 44:510; Lay: Mental imagery experimentally and subjectively considered. Psych. Rev. Mon. 1898. No. 7; Slaughter: A preliminary study of mental images. Am. Jr. Psych. 1902. 13:526ff); in spelling (Abbott: On the analysis of the memory consciousness in orthography. Psych. Rev. Mon. 1909. No.

reagent to vary his processes while at work on a test and often to radically change, in the final test, the methods of work employed in the first.[118] What the variations in processes were has been shown in some detail.

Some indication of the extent of *radical* change in method may be indicated by the following table which lists the cases of such change when it occurred between the first and final tests:

Tests	1	2	3	4	5	8	9	10	13	17	Total
No. of reagents	11	12	12	12	11	10	12	12	12	12	116
No. Changed	6	5	4	0	2	6	4	8	5	3	43

The table shows that *in the ten tests in which the results were the more regular, of 116 difference-scores 43 (35%) were affected by change in methods between the first and final tests.*

The changes are distributed over the reagents as follows: Regular—Mn. 5, Le. 5, Rt. 1, Sl. 2, Ly. 3, He. 3, Cr. 4, Al. 1; 1st Control—Ms. 8, Wf. 4; 2d Control reagents—3, and 4; which indicates that some reagents are more prone than others to radically change their methods of work.

Introspections for some of the tests (No.'s 6, 7, 19) were not sufficiently full in detail to indicate what the changes were, although large variability among the scores of the series of which the tests were composed indicated that they occurred;

44:127ff.). For especially good analyses the reader is referred to Binet (L'Étude Expérimentale de l'intelligence. 1903. Pp. 282, 246, 306-7), Segal Ueber den Reproductions Typus und das Reproduzieren von Vorstellungen. Archiv f.d. ges. Psych. 1908. 12:175ff), and particularly Müller (Zur Analyse der Gedächtnistätigkeit u.d. Vorstellungsverlaufes. Zeits. f. Psych. Erg. Bd. 5, 1911; 8, 1913). The evidence in these references is based almost wholly upon analysis of adult introspections; but it seems highly probable that functional variability is also extensive among children. Binet (*op. cit.*) found this true of his two daughters, and Winch (The faculty doctrine, correlation, and educational theory. Jr. of Phil. Psych. and Sci. Methods. 1911. 8:377) infers it from the fact that the coëfficient of correlation was low for the early series of learning while it was high for the late series, a fact which when found by Hollingworth (Individual differences before, during and after practice. Psych. Rev., 1914, 21:8) with naïve adult reagents, was used to show "that we are not, in early trials, measuring the same thing with all performers."

[118] Change in processes during practice in discussed on pp. 176ff.

the results were so extremely irregular in some of the r tests (No.'s 11, 12, 14, 15, 16, 18) that any statistical tment of them seemed useless.

he extent of variability between reagents may be shown by extent of the range of initial capacity for each test. If is reckoned in per cent of the lowest average (the highest city for a time-unit; the lowest for a work-unit), we get following table:

1.	60	5.	86	10.	149	16.	82
*	135	6.	85	12.	425	17.	122
2.	150	7.	70	13.	76	18.	115
3.	204	8.	133	14.	135	19.	39
4.	33	9.	133	15.	452	**	11

Relative variation of reaction time.
'atigue Index.

1 Test 1 the range of initial capacity in reaction time was of the highest capacity; in relative variability 135%. In 8 the range, in memory of sounds, was 133% of the lowest city. (Uncertainty in scoring ruled out the results of 11).

he range in initial capacities is usually large. In only three s is it below 50% of the lowest average; in six cases it is een 50% and 100%; in eight cases between 100% and % ; in one case 204% and in two cases over 400%. Thus, ver half of the tests the highest initial capacity is more than le the lowest.[114]

)ur tests are not peculiar in showing frequent wide ranges in initial ity. On p. 67 we had occasion to refer to Sleight's (*op. cit.* 410-411) n "points"; the range in initial capacities for the three schools is shown ble I to be 27-93, 32-129, 23-132, respectively. Binet's (L'Étude expéri-le de l'intelligence. 236ff) two daughters upon the test of marking out tters *a, e, d, r, s,* from French text made initial scores of 23.1 and 53.4 ctively; and his six dull and five bright boys upon the same test (At-n et Adaptation. 364ff) ranged from 61-165 and 68-138 respectively und Meumann's (*op. cit.* 15, 47ff) six reagents ranged in memory span umbers 5-9, in learning nonsense-syllables 13-41 presentations, note-form ols 25-60, sickle-form symbols 33-75. Thorndike and Woodworth's *cit.* 253ff, 385, 556) reagents ranged in average error in estimating areas, .2, 10.5-28, 9-21.9, 5-47.8, 12.6-47.4, 4.5-14.7, 20.1-37.8, 23.7-62.6, etc.; and in

Initial capacity, as the term has been used in these pages, denotes the average of the scores of the series of experiments constituting the first test. And since the results of all the tests, except No.'s 2, 3, 11, 15 and 16, were made up of averages of from four to ten scores of individual experiments or of series of experiments, the variation in initial capacity as here represented is not as great as would be shown had the initial scores been selected.

The result of (a) change in processes between first and final tests and (b) the variability in initial capacity is a great reduction in the strictly comparable difference-scores between the eight regular and the four control reagents.

If the number of cases is selected from the tables reproduced in the discussion of The Test Results above (pp. 106ff.), we get the following table:

Exp.	Groups	Group	Regular	1st Control	2d Control	Total
1.	4	2	2	1	0	11
2.	6	0	0	0	0	12
3.	4	4	4	1	0	12
4.	4	1	2	1	1	12
5.	3	1	4	1	0	11
6.	3	1	1	2	0	11
		2	5	0	1	
		3	1	0	1	
7.	3	1	2	1	0	11
		2	3	1	0	
		3	1	0	2	
8.	4		0	0	0	10
9.	4	2	3	0	1	12
10.	4		0	0	0	12
13.	4	2	1	1	0	12
17.	4	2	2	1	1	12
19.	5	3	5	1	0	11
	—	—	—	—	—	—
Total			36	12	9	149

To interpret the table, variation in initial capacity classified the reagents in Experiment 1 into 4 groups; the only results of both regular and control reagents to fall within a single group were two of the regular and one of the 1st control reagents in Group 2; 11 reagents took the test.

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time in marking out words, 170-232, 175-306. Culler's (Interference and Adaptability. Archives of Psych. 1912. 3: No. 24:16) nine reagents in the

The tables of relative variation in reaction time (of Test 1) and the "Fatigue Index" (of Test 19) are omitted in this table.

The aggregate of cases in which the difference-scores fall into some group in which comparison can be made is 57 (38%) out of a total of 149.

And if the averages of tests in which the results were sufficiently irregular to be omitted, are combined with these, *out of a total of 219 difference-scores we have but 57 (26%) which are comparable.*

g. Causes of Variability

The more general causes of variability in a reagent's work were conditions of health, relative freshness or fatigue, emotional conditions, attitude toward the work of the test, etc. Incidental causes occasionally occurred such as, cold hands in reaction tests, winking at the moment of a rapid exposure, accidents in manipulation of keys, or in handling pen and paper in recording, unusual distraction, influence of preceding laboratory work (He. and Wf. in reaction to sound), mental practice (Wf. in typewriter reaction), *etc.* More specific causes varied in accordance with the nature of the work in the test, but may be described in general terms as, voluntary or undesigned shifts of the attention to various elements of the processes engaged, changes in the extent of the distribution of the attention over part-processes and their coördination, constructing of more adequate methods, and practice-effect in dropping out of the process unessential factors, in heightening sensitivity, discrimination, reproduction, habituation to distraction, and in building up habits of higher order.

To these causes are due the serrated aspect of the practice curve of a reagent in any of the tests.

The causes of variation in the results of different reagents must lie in individual variation with respect to the factors described above, and to others in addition to them. An impor-

first group ranged in averages of the first five experiments in the typewriting practice, 20.8-49; the 7 reagents of the second group, 33.2-131; and the 8 reagents of the third group, 28-60. These few samples show the tendency which is likely to be found in any table of initial capacities in mental tests.

tant place among the latter must be given to the 'Aufgabe,' or the task held in the mind of the reagent: Simple reaction, for example, may be 'sensorial' or 'muscular'; and word-completion may involve self-imposed limitations; *etc.*

Radically different methods of work account for large differences in intial capacity or in per cent of improvement (even when based upon equal initial ability).

The low initial capacity of Sl. in card-sorting was due to marked variation in kind of work from the other reagents—his difficult map-scheme used for discriminating the cards and for locating the compartments was the prime element in the difference.

The low initial capacities of Ly. and Sl. in the typewriter-reaction were owing to different work, the prime difference being a difficult coördination of letter and key which interfered with a coördination of the two parts of the process—discrimination, and choice of reaction.

The radical difference between kinds of work was often pointed out in the discussion of Test Results and the effect upon the averages shown. Memory of sounds was effected by kinaesthetic-auditory imagery of the names, by seizing the series as chimes, or by associating the number-names with a visible series; 12-letter-rectangles were learned through a combination of kinaesthetic and visual imagery, or through representative imagery (associations). In the distraction tests (No.'s 14, 18) the difference in the effect of the distraction depended upon variable method in avoiding conflict between the visual or kinaesthetic imagery of the retained letters and the kinaesthetic imagery of the partial sums in the adding process. And the groups into which the reagents were classified according to initial ability, in the typewriter-reaction test, were shown to be valid by analysis of the kinds of work.

Great difference in per cent of improvement was also often shown to be due to difference in kind of work. Sl.'s map-scheme in card-sorting and Ly.'s difficult coördination of letter and key in the typewriter-reaction test, prohibited rapid improvement. The anomalies sometimes found belong here: such as the gain

of Ms., a control reagent, in Test 17, which was greater than that of Al. who trained in the test material for 8 days,—they did not do the same kind of work; Al. consistently gave attention to the whole card, Ms. to a limited part of it; and the gain of the same reagent (Ms.) in Test 13, which was greater than that of either of the two reagents who trained on the test material for 18 days,—she changed to the use of associations.

As to the source of the more specific causes of variation, it lies in part in the practice on the tests themselves, in smaller part in the training (for the regular reagents), but in greater part in earlier experience. Change in the process seems to be effected through the selective function of the attention, by way of adaptation. The need of a discriminating mark for the cognition of the symbols on the cards was met by the selection of map-directions, on the part of Sl., from his schoolroom experience and the relation between diameter and radius, on the oblique pair of cards, was selected from the geometrical experience of all reagents except Le. whom the pair confused; the schemes of classification of compartments in card-sorting, for Wf. and Mn., and of keys or fingers in typewriter-reaction, for Wf., were adaptations of mathematical relations; the grasping of series of sounds as chimes, in memory of sounds, was an adaptation of musical experience; Ly.'s 'sensory set' of consciousness in typewriter-reaction was selected from her training-effects in reaction to sound; and many other changes of method in the final tests were due to the selection of elements that had become prominent in experience since the first tests, often in the training of the regular reagents.

h. The Practice Curve

It was pointed out that the difference-scores of two reagents, even when initial ability had been the same, were strictly comparable only upon the assumption that the respective ways of performing the task were equally susceptible to practice-effect. The fact that scores of *different* reagents measure different processes has its parallel in the fact that scores of the *same* reagent measured different processes; not only because the

reagent changes these processes at random, by design and otherwise, in order to hit upon a more adequate method, but because *practice-effect itself involves change in processes.* This was particularly pointed out in the discussion of the Training Results (pp. 82ff.).

The scores at the beginning of Al.'s training measured letters clearly seen; at the end, letters 'matured' from 'fringe' content of consciousness. The conquest of the 'fringe' content was the means of raising the scores of Mn. and Le. by supplementing the maximum perception and retention of clearly seen letters, and was the proper practice-effect in Al.'s training. Al., however, had not recovered, by the last day of training, from the disastrous effect of this direction of effort, upon the fixing and retaining of clearly seen letters which contributed his highest score on the third day. He was working under the disadvantage of striving to effect coördination of these part-processes and had not yet succeeded.

The early scores in Rt.'s training in learning 12-letter-rectangles measured letters recorded from kinaesthetic-auditory, or kinaesthetic imagery alone (see Analysis Curve, Appendix B. Fig. 17, p. 293). Then, additional letters from visual imagery began to contribute to the score and by the 7th day they reached their maximum. From the 5th day "visual associations" began to contribute as many letters as did the visual imagery, which had maintained its level. *The scores at the beginning of the training measured letters from one kind of imagery—homogeneous letters,—at the end, letters from four distinct kinds of imagery—heterogeneous letters.*[115]

How this change in the material measured was brought about, illustrates accurately what the practice-effect involves:

Rt. at the beginning got a strong visual impression of the letters and then converted it, by pronouncing the letter-names, into kinaesthetic-auditory imagery for retention and reproduction, repeating letter-names over and over during the 10-second

[115] The transition from simple imagery to mixed or complex imagery through practice in memory work was shown by von Sybel (Zeits. f. Psych. 53:338).

interval between perception and recording. But on the first day he found that he could economize time and effort by converting the stimulus immediately into kinaesthetic-auditory imagery and by giving a rhythm to the repetition. The effort to make a strong visual impression was dropped out. This simplification of method was accompanied by a simplification of the kinaesthetic imagery itself through dropping away of the auditory component which formerly supported it. If visual imagery found place at all, it merely supported the kinaesthetic upon the same letters. The reagent found that the 10-second exposure limited the kinaesthetic method of fixing the letters adequately for recall to the first six places. But after repetition had facilitated this process through a readier recall of letter-names in the naming process, and through a more definite rhythm in fixing the letters for recall, some time was gained which permitted attention to note other letters; these extra letters were recorded from visual imagery. This was the first coördination of different kinds of imagery from each of which different letters were recorded. This two-fold coördination then gave way to a three-fold coördination in which additional letters were recorded from "visual associations." The first occurrence of the associations involved the letters CP, which as soon as seen stood for "Chemically Pure." When recording, these letters were found to be very vivid by reason of their association with the familiar phrase; and finding associations became a method. Another three-fold process developed through the habit of intensifying the visual impression of some additional letters while repeating by rote the kinaesthetic group; when recording, it was found that other less vivid letters could be recalled from visual imagery besides those which had been intensified during perception. This three-fold process consisted in the coördination of kinaesthetic imagery, intensified visual imagery, and a secondary visual imagery which seemed to persist in its own strength. By the 10th day a four-fold process was occasionally employed which coördinated all the kinds of imagery already mentioned.

Single-fold imagery was dominant during the first three

days; two-fold coördination was dominant during the 4th, 5th, and 6th days; three-fold coördination became dominant after the 7th day; and four-fold coördination appeared on the 10th day after which it supplemented the three-fold imagery when associations were not found to hold sufficient letters. The single-fold method recurred on the 9th and 14th days; both days of reduced scores (*vid.* Analysis Curves, Appendix B. Fig. 16, p. 292).

The greatest improvement as shown by the practice curve was coincident with the greatest use of the three-fold and four-fold methods; that is, with the highest coördination of the different kinds of imagery. And the rise of the curve is dependent throughout upon the increasing use of the auxiliary forms of imagery. On the 11th and 12th days, when the practice-curve first reached its higher levels, as many letters were reproduced from the auxiliary imagery as from the kinaesthetic imagery, while on the first three days less than a fifth as many were so reproduced.

Other effects of training were: (1) the method of assigning to associations favorable letters other than those occupying the usually preferred 7th and 8th places on the card, (2) the method of recording the letters held in the weakest imagery first, and (3) a more adequate coördination of the recording and reproducing part-processes so that writing down some of the letters ceased to be a distraction on account of which other letters escaped recall.

Per cent of improvement in this training evidently measures change in processes; not merely the more radical changes at the beginning, involved in adaptation to a new kind of work, but those smaller and more orderly changes which constitute practice-effect.[116]

[116] This fact of change in processes during practice is amply supported by the literature, typical references of which follow: Talbot (An attempt to train the visual memory. Am. Jr. Psych. 1897. 8:414-7) by exercising visual recall improved her memory which made more frequent use of visual elements than it had done before. Culverwell (The creation of a memory. Jr. Exp. Ped. 1911-2. 1:160-1) reports an interesting case of improvement through practice in changed mode. Change in processes during practice was shown in reaction-time to words by Berger (Ueber den Einfluss der Uebung auf geis-

Practice-effect in the tests is a source of variability in the test-averages of different reagents. It was not operative in

tige Vorgänge. Phil. Stud. 1889. 5:170-178); in simple reaction-time by Angell and Moore (Reaction time: A study in attention and habit. Psych. Rev. 1896. 3:249-252); in discrimination of clangs by Whipple (An analytical study of the memory image and the process of judgment in the discrimination of clangs and tones. Am. Jr. Psych. 1901. 12:448); in learning paired associates of non-sense syllables by von Sybel (Ueber das Zusammenwirken verschiedener Sinnesgebiete bei Gedächtnisleistungen. Zeits. f. Psych. 1909. 53:338); and in memorizing non-sense syllables by Ebert and Meumann (Ueber einige Grundfragen der Psychologie der Uebungsphänomene in Bereiche des Gedächtnisses. Archiv f.d. ges. Psych. 1904. 4:202ff, 210ff, 228). Philippe (Sur les transformations de nos images mentales. Rev. Philos. 1897. 43:492) and Bentley (The memory image and its qualitative fidelity. Am. Jr. Psych. 1899. 11:47-8) pointed out the characteristics of instability and mutability of imagery which would affect recurrent processes in which it plays a part, and Kuhlmann (On the analysis of auditory memory consciousness. Am. Jr. Psych. 1909. 20:194ff) found that in later than immediate recall of sounds auxiliary visual imagery became more frequently the means of recall. With respect to changes in the processes of recall dependent upon degree of learning J. R. Angell (Determination of mental imagery. Psych. Rev. Mon. 1910. No. 53:70) wrote: "If I am obliged to repeat the words before they are completely learned, my recall is likely to be dominated by visual processes. On the other hand if I am allowed to proceed until the learning is quite perfect, the recall is likely to be mainly in auditory-motor terms, and the more perfectly automatized the act becomes, the more I lose the visual element. Judged at one stage of the process, I should then be set down as a visualizer; judged at another stage, I should be auditory-vocal-motor."

But the most conspicuous cases are shown in studies of learning, in which well-defined stages are related to the curve of practice:

Bryan and Harter: Studies in the telegraphic language. Psych. Rev. 1897. 4:27-53; 1899. 6:345-375.

Swift: Beginning a language. A contribution to the psychology of learning. Studies in Phil. and Psych. (Garman volume) 1906. 297-313, 304ff.

Book: The psychology of skill, with special reference to its acquisition in typewriting. Univ. Mont. Bull. 1908. 53:1-188.

Swift: Learning to telegraph. Psych. Bull. 1910. 7:149-153.

Ordahl: Consciousness in relation to learning. Am. Jr. Psych. 1911. 22:158ff.

Kline and Owens: Preliminary report of a study in the learning process, involving feeling tone, transference, and interference. Psych. Rev. 1913. 20:222-3.

Cleveland: The psychology of chess and of learning to play it. Am. Jr. Psych. 1907. 18:297.

some of our tests, but it was clearly so in others. If it was much greater in the first than in the final test, initial capacity, as expressed by the average score of the first test, is lower relatively, than in the case of about equal practice-effect or no practice-effect in the first and final tests; the difference-score will be relatively too large. The extent to which this source of error was operative in our tests, as well as the frequency of practice-effect in both tests, is shown by the following table:

Tests	1	4	5	6	7	8	9	10	13	17	19	Total
a.	4	6	4	1	2	0	1	1	2	4	3	28
b.	0	5	1	0	0	2	0	0	2	2	1	13

a. Much greater practice-effect in the first test than in the final.
b. Practice-effect in both tests.

In these eleven tests there were 125 difference-scores; 28 (22%) of them are too large because of the greater practice-effect in the first test; and practice-effect occurred in both first and final tests in 13 (10%) cases.

The distribution of the cases over the reagents is as follows:

Regular			Control		
	a.	b.		a.	b.
Mn.	2	3	Ms.	4	0
Le.	4	1	Wf.	2	0
Rt.	2	1			
Sl.	2	0			
Ly.	2	1	—	4	1
He.	2	1	—	2	1
Cr.	1	2			
Al.	1	2			

To be safe in the comparison of difference-scores, such tests should be chosen as are free from the rapid practice-effect of adaptation, or training should continue until initial efficiency is more stable and its quantitative expression more reliable.[117]

i. General Effect of Special Practice

After seeking to avoid error by making the difference-scores as nearly as possible fairly comparable, our quantitative data

[117] For further discussion of this matter, see p. 221f.

for generalization upon the general effect of special practice of the trained reagents are greatly reduced; and in view of the fact that even they are not decisive, our generalizations must remain statements of probability.

With this caution in mind we may examine the cases in which training-effect seemed to show itself in improvement in the tests. These cases are collected in the following table:

Training	Reagents	Tests
Tachistoscopic	Mn.	1, 2, 4, 6, 7,* 9, 10.
	Le.	5,* 8.
	Al.	3, 4,* 8, 9.
Learning 12-letter-rectangles	Rt.	1,* 5, 6, 8, 9.
	Sl.	7, 10.
Reaction to sound	Ly.	4,* 10, 13.
Memory training	He.	4,* 6, 9, 17.
	Cr.	4,* 5, 6, 17.

*These cases were influenced by greater practice-effect in the first test.

Common elements in part-processes, or in modes of attention, are not difficult to find:

Training on the tachistoscope involved:
quick perception (shared by tests 2, 3, 4, 5, 6, 9, 10),
keen momentary attention (shared by tests 1, 6, 7),
reproduction of imagery (shared by 4, 5, 6, 7, 8, 9, 10),
coördination of part-processes (shared by 1, 4, 5, 6, 8, 9, 10).

Training in learning 12-letter-rectangles engaged
quick perception (shared by 1, 5, 6, 7, 8, 9, 10),
rapid kinaesthetic processes (shared by 8, 9, 10),
apperceptive grouping (shared by 9, 10),
reproduction of imagery (shared by 5, 6, 7, 8, 9, 10).
keen momentary attention (shared by 1, 6, 7, 8, 9, 10).
keen continuous attention (shared by 5, 8, 9, 10),
coördination of part-processes (shared by 1, 5, 6, 8, 9, 10).

Training in reaction to sound involved
quick perception (4, 10, 13),
keen momentary attention (10, 13),
quick reaction (4).

Training in memory engaged
keen perception (4, 5, 6, 9, 17),

apperceptive grouping (9, 17),
reproduction of imagery (4, 5, 6, 9, 17),
continuous attention (4, 5, 6, 9).

The probable cases of general effect listed here do not constitute a complete list for which there is quantitative evidence, for cases in which great improvement was in part contributed by change in method were set aside; as may be illustrated by two cases of Mn. There is little doubt that she brought to the test on learning 12-letter-rectangles great advantage from her tachistoscopic training, yet her gain (64%) is set aside because of a radical change in her method induced by her training; there is no doubt at all that she improved in her training, yet her gain (147%) in the test identical with it was for the same reason set aside.

The requirement of setting such cases aside, it will be remembered, is made by the form into which the investigation was cast: the ostensible purpose was to test for the influence of improved conditions of attention, and scores including the advantage or disadvantage of change of method could not be used to measure difference in the capacity of attention. Apart from this requirement, however, there is another ground for discarding these difference-scores, which challenges their value; evidently their service is largely limited to determining the relative advantage of the different kinds of work.

But we do not need to rely upon our quantitative data for proof of general effect of special practice. Introspections indicate it more clearly and more certainly than difference-scores can. Not only are methods of work, and systems of imagery, transferred from one kind of work to another where they are applicable, as the methods of fixing and reproducing 12-letter-rectangles were carried over to memory of consonants serially presented (Rt.), and to digits simultaneously presented (Rt., Sl.), and as the better organization of associations in which letters from 12-letter rectangles were fixed and retained after training in memory (Cr.), but *the process of adaptation to the strange work of the test consists in the selection and application*

of elements of former experience which, when acquired, must always have been 'specific' and which as applied are always 'general.' This principle is not only true of the exceptional and somewhat bizarre cases cited to illustrate unusual variations in the scores, as Sl.'s map-directions in card-sorting, and the grasping of series of sounds as chimes, but it is true of the usual and regular processes of learning to do expertly the work of the test.

The general effect was usually advantageous, as was often pointed out in connection with discussion of change of method, under Test Results, but it is not necessarily so; Ly.'s 'sensory set' of consciousness carried over to the typewriter-reaction from reaction to sound, the attempted transference of training method by Rt. and Sl. to commercial signs presented in the method of training,[118] were disadvantageous. Wf.'s complex scheme in typewriter-reaction, and Sl.'s unwieldy map-scheme in card-sorting, will serve to illustrate the fact of negative influence.

Introspections indicate that the 'spread of training' need not be conscious,[119] as may be illustrated by Cr.'s improvement in learning 12-letter-rectangles which was largely due to better organization of the associations used to represent the letters, a prime factor in the memory-training, yet he was not conscious of applying training-effect. Indeed, *introspections in this type of experiment are not of value because they assert or deny the influence of training upon the tests, although such statements may often be true, but because they describe the processes engaged in both training and tests fully and accurately enough for the presence or absence of specific influences to be determined.*

j. Conclusion

Variability in the mental processes engaged by the reagent on any test was found to be universal; radical change in the

[118] Agreeing with the results of Sleight (*op. cit.* p. 440) that elements may not be available where the whole form will not apply. The fact seems true particularly when the coördination of part-processes has become automatic or mechanical.

[119] Again in agreement with Sleight (*op. cit.* p. 440).

processes between the first and final tests, for the ten tests in which the results were the more regular, occurred in over a third of the 166 difference-scores (*vid.*, p. 168).

Great variability in initial capacity, as represented by the average of the scores of the first test, was also universal; in twenty tables, there were but three cases in which the range of variability was less than half the lower average, 9 cases were between 100 and 200% of it, and two cases were over 400% of it (*vid.*, p. 169).

The effect of these two kinds of variability was to reduce the comparable difference-scores to a fourth (*vid.*, p. 171).

The causes of variability were general, such as health; incidental, such as accident in manipulation of a key or of cards; and specific, such as are involved in adaptation, or in practice (*vid.*, p. 171).

Great difference in the scores of an individual and great difference in initial capacity are signs of great difference in kind of work (*vid.*, pp. 172).

The source of the more specific causes of variation lies in part in the practice-effect of the tests, in less part in the practice-effect of the training, in greater part in earlier experience. Change in process is effected through the selective function of attention, by way of adaptation, and of acquiring skill through practice. Adaptation occasions the more sudden and radical changes, as abrupt change in method; skill through practice involves a more or less orderly sequence of changes depending in nature upon the task but always resulting in a marked difference in the kind of work performed in its initial and final stages (*vid.*, p. 173).

Practice-effect in the tests disturbs the quantitative results; if it is greater in the first than in the final test, the difference-score is too large. Any average which includes it and purports to measure efficiency is not strictly reliable. The extent of this source of error in 'mental tests' may be indicated by the fact that of 125 difference-scores, 22% were affected by greater practice-effect in the first test, and 10% by practice-effect in both first and final tests (*vid.*, p. 177-178).

Recognizing the inconclusive character of our quantitative results, even after the difference-scores were made as comparable as possible, we found 31 cases (7 of which were influenced by practice-effect in the first test) of probable transference of training-effect to the tests, some of which were greatly different in material and method from the training. In all, however, common elements in part-processes, and in modes of attention, were numerous (*vid.*, p. 178ff.).

Introspective data are decisive in indicating the transference of methods of work and systems of imagery[120] from one kind of work to another, where applicable, and that adaptation to the strange work of a test consists in the selection and application of elements of former experience which, when acquired, must always have been 'specific,' and which as applied are always 'general.' This also appears to be a principle of the learning-process, in which skill is attained by smaller and more orderly changes in the processes (*vid.*, p. 180f.).

Transference need not be consciously effected. Introspections are of value chiefly not because of asserting or denying it, but because they describe the processes fully and accurately enough for its presence or its obsence to be seen. And its effect is sometimes negative (*vid.*, p. 181.).

As a measure of attention our tests are inadequate, and the question of transference of improved conditions of attention remains open. That our quantitative results were not more conclusive in showing the effects of training on attention may be owing, in addition to the disturbing influence of great variation in processes and scores, to certain limiting conditions under which the experimentation was conducted: (a) Change in method between tests rules out the results as a measure of change in attention; (b) our reagents were university students whose habits of attention were pretty well established by former training; (c) our trained reagents were more mature than the control reagents and were experienced in laboratory work; (d) our period of training was relatively short (six weeks, three days per week); (e) our tests could not be long enough to give a reliable measure of initial ability, because of inter-test

[120] In agreement with Fracker (*op. cit*, pp. 90ff.).

practice-effect; and (f) adequate introspections were limited almost wholly to the trained reagents.

The contribution of the experiment lies principally (1) in revealing the nature and the extent of variation in mental processes, both between different reagents and with an individual reagent, which may be expected when such 'tests' as ours are given under favorable laboratory conditions to intelligent young men and women; (2) in showing how such variation affects the scores; and (3) in offering suggestions toward improvement in this type of experiment.

The interesting question of how statistical method is affected by these considerations is discussed later (pp. 219 ff.).

2. Experiment on Reproduction

The purpose of this experiment[a] was (a) to supplement the Experiment on Attention by a more intimate knowledge of the factors of variation, through greater refinement of introspection and analysis, and (b) to set the conditions to test for a subtle but definite 'spread of training.'[121]

To meet the former aim, tests were chosen or devised which offer opportunity for introspection separately upon the successive 'moments' into which they naturally fall, or for fuller description of the processes used in acquisition and reproduction by reason of the material used in them.

To meet the latter aim, the tests and training were arranged to exclude the transference of methods of work or of systems of imagery, such as belong rather to the grosser and more radical changes in work, due to what was termed "adaptation," than to those smaller and more orderly changes which constitute practice-effect proper.

It will be remembered that the most definite cases of the general effect of practice which came to notice in the preceding

[a] Performed during the year 1911-1912.

[121] For the distinction between 'Spread of Training' and 'Transference,' see footnote to p. 225, and the text on p. 230.

experiment were of the nature of 'transference,' but that there was also some indication of 'spread of training'; and that it was this latter sort of general practice-effect that was found in the earlier experiments on Marking-out Words, Discrimination, and Reaction with Discrimination and Choice.

The susceptibility to improvement of the capacity to 'mature' and reproduce weak imagery in the tachistoscopic training, in the Experiment on Attention, suggested reproduction of imagery as the work of this experiment.[122] Consequently, tachistoscopic and memory tests were devised and made to differ radically in method and material from the training, in order to avoid 'transference' and to invite 'spread of practice'; a further test which differed from the training but slightly in material, and method, was included to determine if so slight a difference might cause interference.

The training chosen was sound discrimination, and in order to insure practice in reproduction of imagery of some sort, the time-intervals between the two sounds to be discriminated were varied between 7 and 60 seconds, and series of sounds were made to vary widely, as a whole, in intensity.

The tests were designed to measure the capacity to reproduce imagery occasioned by the presentation of materials of different

[122] This process, or group of processes, so far as it lies above the threshold of consciousness, may be represented by a tension of attention under the influence of 'determining tendencies' analogous to the experience of recalling a name that seems close but delays in coming; conceivably, however, it also takes place wholly under the threshold, operates in part from "Unconscious psychical stimuli" (Lipps: Grundtatsachen des Seelenlebens, S. 125), involves as subtle processes as the "unconscious associations" reported by Scripture (Ueber den Associativen Verlauf der Vorstellungen. Phil. Stud., 1892, 7:78, 136), Jerusalem (Beispiel von Assoziation durch unbewusste Mittelglieder. Phil. Stud. 1894. 10:323-5), and Thomas (Ein weitres Beispiel. Zeits. f. Psychol., 1896, 12:60). *Vid.* Footnote on p. 87. Statistical evidence of the influence of subliminal impressions upon judgment is to be found in experiments in discrimination (where Right Cases fall off regularly with the magnitude of D) (*vid.* Appendix D, p. 299, and Peirce & Jastrow, quoted by Donaldson in The Growth of the Brain, p. 292), and has been reported from experiments on Guessing by Sidis (Psychology of Suggestion. 1898. 168-171) and Stroh, Shaw and Washburn (A study in Guessing. Am. Jr. Psych., 1908, 19:243-245).

It is perhaps not necessary to point out that provision for introspection in this experiment is for other purposes than for a direct determination of the presence of these subtle processes or of increase in their efficiency.

kinds, and the training was designed to develop greater power in reproduction of imagery of a certain simple kind.

The method of experimentation was the same as the preceding. Three groups of reagents took the series of tests before and after an interval of from five to seven weeks. The first group took training during the seven weeks; the second group took all the tests before and after a free interval of five weeks; the third group took but one pair of tests each before and after a free interval of five weeks. Each pair of tests was therefore taken by three trained reagents, three control reagents who took the other tests also, and two control reagents who took no other tests.

The trained reagents (Hs., Wn., Rt.) were seniors in Psychology, English and Education, respectively, who were doing advanced laboratory work in Psychology. The first group of control reagents (Al., Hhs., Br.) were a freshman and a sophomore in Psychology, both pursuing elementary laboratory work, and a freshman in Economics who had no laboratory experience. The second control group (Ck., Pn., An., Ty., Dn., Hn., Hd.) included five seniors, one sophomore, and one freshman, representing the German, History, Education, Economics, and Pre-Legal departments of the university.

a. The Tests

Test 1. *Recognition or choice of one of two letters.* The purpose of this test was to give a measure of the liability[123] of reproduction. The apparatus was the same as that used in the Tachistoscopic test (No.17) of the preceding experiment. The method was (a) to expose a 12-consonant-rectangle 0.1 Sec., (b) after a 3-sec. interval to expose two letters printed like those printed on the rectangle, one of which was to be chosen by the reagent as having been on the card and to be recorded in the section of a ruled form corresponding as nearly as possible to its position in the rectangle, (c) to time with a stop-watch the interval between the exposure of the two letters and the vocal choice of one of them. Rectangles were presented at the rate

[123] For use of this term, *vid.* Külpe: Outlines, p. 197.

of one a minute. Fifty experiments constituted the test. All judgments carried an index of one of four grades of certainty as to the letter's existence on the card and as to the position in which it was recorded. Introspections were made upon four different intervals or moments of the experiment: (1) From "Ready" to the stimulus, (2) Perception, (3) On the interval of 3 seconds between perception and the appearance of the two letters, (4) The moment of recognition or choice.

The two letters shown for choice were so selected that they were distributed evenly over the 12 spaces of the card, that each letter was on the card one-half times as often as it was exposed for choice, and that it occupied the second position as often as it did the first in the presentation for choice; thus it would be possible to learn if any part of the card is favored in perception, if there were favorite letters, if the right or left letter presented for choice is favored, all of which would be sources of error, and under the conditions of the experiment would tend to bring the score of R cases toward the probability figure of 50%; Reproductive tendencies would be shown by the excess over 50%. Fifty experiments constituted the test.

Test 2. *Reproduction and recognition of letters on 12-letter-rectangles.* The apparatus was the same as that used in the preceding test. The method was only slightly changed from that of Test 17 in the Experiment on Attention. 12-Consonant-rectangles were exposed 0.1 seconds; 10 seconds were given in which to record the letters perceived; the card was then re-exposed for 15 seconds while the reagents recorded in pencil other letters recognized as having been seen but which failed to be recalled. The rate of experiments was two minutes. Introspections upon process and imagery were written and the following intervals of the experiment were treated separately: (1) From "Ready" to stimulus, (2) Moment of perception; (3) Upon the interval before recording, if there was one; (4) Interval of recording; (5) Interval of recognizing further letters. Twenty experiments constituted the test.[124]

[124] See Appendix C, p. 295, Method "Text (2)," for values used in scoring the results.

Test 3. *Discrimination of sounds.* The same as No. 7 in the Experiment on Attention; the same series of intervals were used (*vid.* Appendix B. Fig. 7, p. 290) and the stimuli were given with the same instrument—the sound pendulum. There were 10 series, of 9 judgments each, in the test. Introspections were taken on the process. The per cent of R cases was to constitute a measure of the sort of reproduction upon which training was taken; it being assumed that some sort of reproduction of the first stimulus, or of some function of it, was necessary to render judgment upon the second.

Test 4. *Memory for visual symbols.* Reproductive tendencies could be measured here by the amount of correct reproduction from a single presentation, and by the number of repetitions necessary to learn completely a series of 12 symbols; both measures were attempted. The Müller and Schumann memory apparatus was set at one revolution in 44.5 seconds, which presented the symbols at the rate of 1.07 seconds. And when the series was repeated, presentations came at the rate of 44.5 seconds, leaving an interval of about 33 seconds between the end of one and the beginning of another. The number of revolutions was recorded by the apparatus. The symbols were of the same kind as those used by Ebert and Meumann,[125] one series of symbols resembling notes of music with the flags variously located; the other, of symbols resembling sickles, both elements changing in absolute positions and in relation to each other.

The first part of the experiment consisted in reproduction of as many symbols as could be remembered from one presentation each of two series of six symbols; the second part, of learning two series of 12 symbols by heart.

b. The Training

Three 4th year students (Hs., Wn., Rt.) took the training in Sensible Discrimination of intensities of sound, which extended over a period of 48 days and consisted of 31, 59, 60

[125] Archiv f.d. ges. Psychologie. 1905. 4:49; samples of these forms are also illustrated by Thorndike: Educational Psychology, vol. II, p. 369.

series, 9 judgments per series, taken upon 7, 11, 13 days, aggregating 279, 450, 540 judgments respectively for Hs., Wn.. and Rt. The training was taken between 2:30 and 3:30 p.m., and continued about 45 to 55 minutes. The room during the experiment was kept closed and much darkened, and the reagents kept their positions constant, about 4 meters from the source of the sound, with their backs toward it. They took the training together and secured privacy at a long table by partitions of wooden screens.

The sounds were produced by dropping steel balls from magnets upon a steel block, by the use of Krueger's "Fall-phonometer."[126] Manipulation was noiseless. The weights of the pairs of balls were:

1. 5.56 grams
2. 8.33 "
3. 11.86 "

and the heights from which they fell, and their relative intensities of sound were:

Intervals	cm.	Intensity
9	96	1.78
8	84	1.55
7	72	1.33
6	63	1.17
5	54	1.
4	47	0.87
3	40	0.74
2	35	0.63
1	30	0.56

These steps in intensity are about one-half a noticeable difference.

The 54 cm. fall was used for the norm, and it with all the rest for variables; but by using the three pairs of balls, three norms of varying intensities (1.00, 1.50, 3.13), with their corresponding series of variables, were obtained. Judgment was given upon the second sound, and the latter was the norm as often as it was the variable. The time intervals between the two stimuli were equally distributed over 7, 15, 30, 60 seconds.

[126] Similar, in principle, to illustration in Wundt: Grundzüge d. Physiol. Psych. (5te Auf.) I: 512.

These changes in intensity of the norms and in sequence of variable and norm were intended to prevent an easy classification of the first stimulus and to favor its being held in some sort of imagery; and the temporal intervals were made various lengths to make the retention or recall of that imagery necessary, and to facilitate a checking up of this fact by comparison of the number of the Right and Undecided cases for the various intervals. The method was that of constant difference, Right and Wrong Cases; procedure without knowledge.

c. Training Results

(1) *Processes*

Hs.

At the beginning and throughout the training Hs. held the auditory image of the first stimulus, or brought it back with more or less effort, and compared it with the auditory sensation of the second stimulus (1, 32). But there were variations from this general method:[127]

[127] In the deviations from the simple direct comparison of auditory imagery which resulted in the training-series of these reagents, it is possible that reproductive processes of some sort found place. Whether the simple auditory impressions were supplemented or actually replaced by complicated auditory imagery or imagery from the other modalities (visual, tactual, kinaesthetic), or comparison was dispensed with in 'free' judgments, it would seem that imagery representing the first stimulus, or an organic reaction to it, mediated judgment. That these deviations are frequent, results largely from the fact, pointed out by Whipple (An analytical study of the memory image and the process of judgment in the discrimination of clangs and tones. Am. Jr. Psych., 1902, 13:259), Slaughter (A preliminary study of mental images. Am. Jr. Psych., 1902, 13:526ff), Kuhlmann (Problems in the analysis of the memory consciousness. Jr. Philos. Psych. & Sci. Meth., 1907, 4:5ff), and others, that the auditory image is not simple and that it sometimes loses itself in its other-modal or organic constituents; and partly from the impulse, insisted upon by Woodworth (Non-sensory components of sense perception. Jr. Phil. Psych. & Sci. Meth., 1907, 4:169ff), to clothe the sensory impression with ideational, perceptive, or emotional attributes. Bentley (The memory image and its qualitative fidelity. Am. Jr. Psych., 1899, 11:7), quoting Külpe, reminds us that reproductions are not weakened copies of sensations, that reproduced sensation is schematic, needs aids (words, movements, organic sensations, feelings) to complete recollection, and adds that these aids may become the real vehicle of retention.

Sometimes the image of the first stimulus is overcome by other imagery or by distraction: In one instance visual imagery of E manipulating imaginary apparatus crowded it out, after which it was recalled (1). When she was nervous or tired the auditory image was apt to get away, especially during the longer intervals (18, 25); then she was particularly conscious of distraction—wind whistling by the windows (26), the stop-watch ticking (31), a throbbing noise down stairs (55) which rendered the renewal of the image very difficult or even impossible. "Lost image entirely . . . was going to judge '?' when it returned and I was quite sure that my judgment 'greater' was correct" (22:5, Norm-Variable 9, 60," Right).

Instead of comparing the image of the first stimulus with the sensation of the second she sometimes had the feeling of converting her image of the first into sensation and of comparing sensations (1), or in uncertainty she compared images of both (26:8); occasionally she interpreted intensities as qualities of pitch and translated tonal imagery into intensity (14, 46); she also based judgments on extraneous imagery as "the feeling in the hands of noise from wooden blocks" (29), and other kinaesthetic images in hands and arms (32:3, V3N—15"). In some series she did not try to hold the image of the first, but often brought it back after the second stimulus was received (36, 41). In some cases she made 'free' judgments: "I lost the image entirely, yet when the second stimulus came it was very clearly 'greater' . . . it was startlingly loud" (39:2,—NV8—60"—R); "I could not bring back image of the first stimulus, but I was certain that the second stimulus was 'greater'; I think I judged more by the way it startled me than by anything else" (42:1,—NV7—60"—R).

The judgment 'like' sometimes meant that (1) the "sensation exactly fits in with the retained or renewed auditory image" (1), and is given with a feeling of certainty (21); and (2) the identity is doubtful (26).

Introspective notes as to certainty in a series correlate with the number of R judgments (28, 29).

Relief was felt when the intervals were short; the effort to

renew and strengthen the image of the first stimulus is spared (27:9).

Her training was taken under trying circumstances, occasioned by events not connected with her university work, which made her very nervous and given to abstraction. She omitted series 3-17 and 47-49 inclusive.

Wn.

Particularly at first and somewhat all through the training Wn. retained or revived images of the first stimulus in order to pass judgment upon the second; comparison however was difficult: "I seem to compare the first stimulus I have retained through images, with the second stimulus as soon as I hear the latter. When I have tried to compare them both as images I have found great trouble in keeping each clear in my mind; they have tended to overlap each other" (3). This difficulty in comparing images is mentioned several times (6, 8). Nevertheless to pass judgment upon the sensation of the second stimulus, the image of the first seems necessary: "I find that if the first is not in my mind as one image or another when the second is sounded, I have great difficulty in comparing the two. It requires constant attention to keep it there," (6). The holding or reviving images is mentioned in series 1, 2, 3, 14, **17**, 20, 21, 22, 28, **38**, 41, 48. It was resorted to in the heavily typed series (17, 38) upon inability to classify the first stimuli or to attribute to them a personal quality.

The images are strong just after the first stimulus has sounded, but soon fade (2), are very hard to retain (6) or to revive after they have disappeared. Often they are recalled by the second stimulus (7, 12, 26).

The imagery seems rarely purely auditory. It is usually auditory and kinaesthetic, the latter taking the dominant rôle, especially in reviving a waning or lost impression (2, 3). In this the throat, head, and hands, are chiefly instrumental (1, 4, 7, 11, 13, 14, 20, 28, 41). Sometimes the kinaesthetic image is based on a "singing" of the first stimulus, intensity being interpreted as pitch (15, 28, 41, 49); rarely is the pitch held

in auditory imagery of another's voice (43, 48). Occasionally the sounds are interpreted as 'stronger' instead of 'greater' (4); and value is given in terms of "sensations of being struck" (1). Judgments were sometimes based upon the "startling effect" (3, 4a), or a "sensation of surprise," (5). Visual imagery played some part but was usually recognized as a distraction (4, 13); sometimes, however, as an aid (13, 14, 20, 27). It took various forms: "a piece of steel being snapped" (1, 13, 20); "E working with the apparatus" (4, 11, 14, 27); "a piece of steel hitting a bar of iron" (4); and such as attended associations involved in attributing personal qualities to the stimuli (43).

Other modes of passing judgment developed early and continued throughout the training. The beginning of the method of classification resulted from a noted "familiar" quality of the first stimulus as a sound that was heard before and is now known (8, 9, 36), and a comparison of the first stimulus with preceding first stimuli (10, 11). This led to classification as "very loud," or "very soft" (10, 11, 14, 18), which developed into a method (20, 30, 31, 41, 49): "I have developed quite a system of classification of the first stimulus as 'very large,' 'large,' 'small,' 'very small,' etc., so that I have no difficulty in recalling it upon hearing the second. I do not even have to think of it in the interval when the first stimulus is very decided one way or the other" (30). The first stimulus was then retained in verbal-motor imagery. Sometimes this method failed, however, and she had to fall back upon auditory-kinaesthetic imagery (33). Upon the break-down of this method, another was developed, suggested probably by an early instance (13:6) in which a loud stimulus brought to mind a very aggressive man of her acquaintance. Qualities of personality were conferred upon the first stimulus (13, 35, 36, 37): "From classifying the stimulus in a general way as 'very great,' 'great,' etc., I have come to attributing qualities; as, aggressiveness, timidity, power, weakness, etc. I find that by doing this I can remember the stimulus easily when I want to compare it with the second stimulus and need not think of it during the interval, as is the case when I try to retain it by image" (35). Sometimes, how-

ever, the stimulus failed to suggest personal qualities (38); "In such cases I fell back on the images, auditory-kinaesthetic, for a comparison, and was usually able to recall them" (38).[128]

The obvious economy of these two methods in the longer intervals of 30″ and 60″ is probably responsible for their use.

'Free' judgments were seldom made (26.3).

'Like' judgments were usually based upon "similar effects—same kind of sensations" (1), or "the same sensation of surprise" (4).

The short intervals (7″, 15″) were a relief (10), the long ones difficult (18, 23, 47), especially because the retained imagery may not belong to the last experiment.

The heavier balls were also a relief (16, 22, 46); the weaker sounds were hard to retain and hard to classify (33).

When the norm was the first stimulus it was often thought to be varying (17).

Emotional factors probably played some part in determining judgment: Sometimes the second stimulus was anticipated (5); reagent was worried because there were so many 'less' (20, 43) or 'greater' (24) judgments occurring in the series; or upon giving several 'like' judgments she tried to make the rest either 'greater' or 'less' (32). Conferring personality was an "interesting" process (36) and may have urged attributes not appropriate.

The 'type' as shown by an assembling of the data is verified by introspection: "I am surer of 'less' than of 'greater' judgments" (5). The R judgments for the cases in which the second stimulus was 'less' greatly exceed those of the cases in which it was 'greater.'

Rt.

Rt. insists that no image of the first stimulus remains during the interval (1, 2, 4): "In fact if I try to keep it in mind I am not sure that I succeed as well as when I don't try to do so" (1); but "an idea of the intensity of the first stimulus remains—though not in auditory imagery" (1:7). "I do not carry the image over the interval; I do carry a sort of estimate of the

[128] That methods and standards of judgment alter in training was shown by Whipple's reagent O. (Am. Jr. Psych., 12:448).

comparative loudness of the first sound: I cannot say just how I form the estimate" (5). At the beginning of the training, therefore, he began to classify the first stimulus which relieved him of carrying an auditory image. But there were times when the image of the first stimulus was distinctly recalled just after the second was received: "On the appearance of the second sound there must be a recall of the 'idea' of the loudness of the first sound, and I think the actual sound arouses an auditory image of the first" (36).

As the training progressed, judgments were confidently given when no image or idea of classification was present (28), and it became difficult to introspect (31). The following is a description of the process written after the last series:

"I have a 'mental estimate' rather than an auditory image of the sound. There must be a vague fleeting imagery with this 'mental estimate' for if the interval is long this estimate is less definitely placed, is more elusive and fleeting and vague. A sort of 'stock pattern' of degree of loudness remains. This concerns only the interval. On the appearance of the second sound I am more able to judge than I expect to be" (49).

There are many protests against the long intervals (1, 2, 3, 10) the reagent claiming that he loses attention; this would seem to indicate an effort to carry imagery along.

Judgment was usually given quickly or upon the appearance of the second stimulus (2, 3). The most satisfactory state of the attention was not the highest (2), and the reagent complained that it was often poor (4, 6) and often that the sounds seemed vague (13, 14). Distraction was often noticed (5, 18, 26, 27, 35, 41).

The judgment 'like' merely meant no perceptible difference (1:8, 4:6).

The reagent's 'type' is verified by his introspection upon the last day: "The long interval I feel makes the second sound seem louder. The first is fading in intensity and clearness and is becoming flitting in its recall. . . . There is either an unusual number of judgments 'greater' or else I have a decided preference for them in series 48 and 49."

(2) *Quantitative*

In reckoning Right and Undecided cases (a) judgments upon D=o are discarded,[129] (b) 'Doubtful' and 'like' judgments are aggregated as Undecided; (c) per cent is reckoned upon the total number of judgments upon D>o.

With the intermediate weight of ball a series of judgments yield a slightly greater per cent of R cases when the fall-phonometer is used (as in the training) than when our test series is given on the sound-pendulum (as in Test 3). The following table gives the results of Rt.: (80 judgments each).

Sound Pendulum		Fall-Phonometer	
R	U	R	U
62.5%	27.5%	65.0%	22.5%

All other conditions remaining the same, a greater per cent of R cases occurred (a) when the absolute intensities were greater (heavier balls being used), (b) when the time-interval between the stimuli was 15″, (c) when the second stimulus is the less, for Hs. and Wn.; when it is the greater, for Rt.

From the following table, showing the number of R cases in 96 judgments on each time-interval, in seconds, it appears that "imagery" of some sort was more or less used:

	7″	15″	30″	60″
Hs.	46	57	48	43
Wn.	51	61	54	59
Rt.	63	68	61	54

The 7″ interval was not sufficient for the imagery to become settled. The imagery seemed to dim with the flight of time; only for Wn., who used classification more consistently—an indirect method,—was the longest interval as favorable as others.[130]

[129] *Vid.* p. 43, footnote.

[130] The indication of the dependence of judgment upon memorial factors becomes more definite if we separate the judgments according to the relation of the intensity of the second stimulus to that of the first. Assuming, from the work of Ebbinghaus and others, some of whom are noticed below, that the memorial factor dims with time, one should expect (1) Overestimation of the second stimulus, (2) A falling off of Right Cases with time, in the gross averages (as is shown in the table above), and (3) upon segrega-

If the R judgments of the training are aggregated for each of the reagents respectively, their relative efficiencies may be compared: Hs. 50.4%, Wn. 58.6%, Rt. 64.1%.

A peculiarity of the training is that instead of improvement

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ting the data as suggested, a general restriction of this decrease in R cases to the group in which the second stimulus is less than the first. This third expectation is fulfilled in the following table (Per cent of judgments reckoned upon all judgments upon D>o):

			7″	15″	30″	60″
$S_1<S_2$						
	Hs.		23	55	36	53
	Wn.		33	58	54	69
	Rt.		63	71	77	71
			—	—	—	—
		Avg. %	40	61	56	64
$S_1>S_2$						
	Hs.		69	56	57	34
	Wn.		71	67	63	54
	Rt.		69	71	50	40
			—	—	—	—
		Ave. %	70	65	57	43

The first expectation enumerated above, is met by all reagents when the stimuli were given 60″ apart, and by Rt. in gross averages. It is opposed by 'Type' in the shorter intervals for Hs. and Wn. Another influence to veil in slight measure the fulfillment of these expectations is the presence of 'absolute' or 'free' judgments, shown by all reagents in excess of R cases in Order N—V over Order V—N; it amounts to about 7% of all R cases on D>o.

Our results conform pretty well with the literature. The over-estimation of the second stimulus (the Fechnerian Time-Error—*vid.* Psychophysik I:88) has been found with musical tone by Wolfe (Phil. Stud. 3: 556), with intensities of sound by Starke (Phil. Stud., 3:270ff), Merkel (Phil. Stud., 4:117ff), Lehmann (Phil. Stud., 7: 205), and Tschisch (Zeits. d. Psychiatrie, 1896), with memory for passive movement by Schukowsky (Zeits. d. Psychiatrie, 1899), with discrimination of shadows by Gerwert (Zeits. d. Psychiatrie, 1899, No. 8), and with discrimination of shades of gray by F. Angell (Phil. Stud., 19: 5).

A falling off of R cases with increase in time between the stimuli is shown by Wolfe (*op. cit.* p. 569), Tschisch (Dritter Int. Kong. f. Psychol., 1896, p. 103), Gerwert (*op. cit.*), and F. Angell (*op. cit.* From Table III, pp. 12-13).

The general restriction of this falling off of the R cases with time to the group $S_1>S_2$ cannot be well illustrated from the literature for the reason that this group cannot be segregated from the other ($S_1<S_2$) in the tables; it is

retrogression was shown in R judgments, although Undecided judgments decreased. The following table gives the per cent of R and U cases for each third of the training:

	R			U		
	1st	2d	3d	1st	2d	3d
Hs.	....	51.1	48.8	....	33.8	30.0
Wn.	60.0	58.8	57.5	18.8	26.3	18.8
Rt.	63.8	68.8	60.0	25.0	16.3	13.8

The only improvement indicated is in Rt.'s intermediate part of the training. This may mean that no increase in reproductivity took place as a result of the training, in which case, if we may judge from the results of the single reagent in the Experiment on Sensible Discrimination (p. 45) who failed to improve with practice, no improvement is to be expected in the tests. It will be seen in the test results that in Test 3, on this same process, Rt. is the only trained reagent who shows a gain and that is insignificant in amount.

But on the analogy of Al.'s training in the Experiment on

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shown, however, in the data of Table III in F. Angell's research on the Discrimination of Shades of Gray (*op. cit.* pp. 12-13) which we segregate and present in per cent of R cases as follows:

		5"	15"	30"	60"	Avg. %
$S_1 < S_2$	Al.	61.9	60.4	67.3	72.2	65.4
	Bt.	53.5	48.2	55.7	65.6	55.7
		57.7	54.3	61.5	68.9	
$S_1 > S_2$	Al.	63.0	53.7	46.4	47.5	52.7
	Bt.	67.7	70.7	65.2	55.0	65.3
		65.4	62.2	55.3	51.3	

When intervals of from 5 seconds to 60 seconds have been used between the stimuli, optimal intervals greater than 5 seconds and less than 30 seconds have been shown by Gerwert (*op. cit.*), Tschisch (Dritter Int. Kong. f. Psychol., p. 103), Wolfe (*op. cit.*), and Angell (*op. cit.* p. 5).

Influence of 'Type' was shown by Martin and Müller (Zur analyse der Unterschiedsempfindlichkeit, pp. 128-134), Kämpfe (Phil. Stud., 8:582), and F. Angell on Discrimination of Clangs (Am. Jr. Psychol., 12:72).

A good critique of the variable influences upon R cases in this type of experimentation is to be found in Martin and Müller (*op. cit.*, pp. 17ff) and in Angell's review of the same in the Am. Jr. Psychol. (11:266ff).

Attention, there may have been some change made by the training which the scores failed to show. Analysis rather than scores must be relied upon to determine this, and it was seen in the analysis of processes that change did take place.

d. Test Results

(1) *Recognition or Choice of One of Two Letters*

The method of this test favors analysis of both introspective and quantitative results for determining many of the factors of variability in the processes involved in a task which seems quite simple and definite.

(a) Introspective Analysis

If one experiment be divided into four intervals upon which introspections were recorded, the method of the reagent and the accompanying processes may be stated as follows:

1. *Interval between signal and stimulus (2 sec.).* A settling of the body into a comfortable (Al.) or a strained (Hhs.) attitude, a direction of the gaze upon the window of the screen, sometimes with the head at a slight angle (Wn.); Consciousness may (1) contain keenly the purpose of (a) seeing the whole card, or (b) a definite portion of it, or (2) the mind may be a blank (Hhs.). If perception of the whole card is intended, the center of the window may be keenly fixated or the gaze may be not so limited spatially. The trained reagents appear to have been more constant in holding a single purpose, though all reagents varied some in this respect during the 50 experiments of the test; the control reagents did more experimenting especially in regard to the extent and location of perception.

2. *Moment of perception (0.1″).* A more or less dim image of the whole card may result, but usually one line or a group of letters stand out more clearly, while the rest of the card may present some dim imagery or may appear blank. Sometimes the presentation was read (verbally) from left to right or from top to bottom; sometimes just seized as a whole, visually. The grades of clearness of the letters did not follow from the purpose, except in cases where perception was narrowed to a

small part of the card. From 2 to 5 letters were the usual number that occurred in clear imagery.

3. *Interval between the perception and the presentation of the two letters (3″).* Visual imagery was held and often read as far as clear letters appeared; effort to 'mature' dim imagery, and to locate the letters seen. Sometimes a vivid hope is entertained that certain of the clear letters will be exhibited. There was noted a feeling that more letters than those perceived would be recognized if shown (Rt.).

4. *Moment of recognition or choice.* If one of the two letters shown had been clearly perceived, it was instantly named; if neither had been clearly seen, effort was made to determine which had been on the card and one was chosen because it "seemed more familiar" either to sight or by pronunciation, because it brought back a vague image of the card, because its form was more pleasing, because of certainty that the other letter was not seen; or the choice was a "pure guess." Since the imagery was in all grades of clearness, certainty of judgment graded down from very certain to wholly uncertain. Four grades were recorded. "Very certain" was given for very clear visual or kinaesthetic or combined imagery; "Certain" for less clearness; "Not just certain" either for such imagery as would support the choice of a similar letter, or for vague imagery; "Wholly uncertain" for very vague imagery or for none. Sometimes a letter was recognized as having been seen, while in process of pronunciation (Hs.). Other cases of 'maturing' imagery adequate for recognition, concurring with the feeling of familiarity, and efficiency in recalling a vague image of the card, referred to above, are indicated by changes in choice. That vague imagery often determined undecided judgments is shown by the record of the influnce of the 1st, 2d, and 3d preceding cards.

(b) Quantitative Analysis

Analysis of the quantitative results reveals some additional factors of variation in processes, indicating further complexity of the processes engaged in this simple task, and shows in what way training of the regular reagents affected these processes.

The range of initial capacity was from 48% to 76% R cases, and its average of 61% was increased in the final test by 2%. But increase was not uniform, nor do the regular reagents show any advantage over the control reagents, and it will be made evident that these scores cannot be taken as a measure of reproduction or, in fact, of any other capacity. The first patent indication that they measure greatly different processes is the fact that the results of two control reagents are directly opposed to each other: Al. made the highest score in the first test, and the lowest in the final, losing 18%; Ck. made the lowest score in the first test and made the greatest gain (12%).

Letters were chosen by all reagents with four degrees of certainty each of which involved different processes, as is shown not only by the introspections but by the regularity of their quantitative results when the latter are aggregated:

	VC	C	NC	U
% R cases	94	73.6	56.3	49.4
Avg. time of choice	1.22″	1.47″	1.68″	2.16″
Avg. space error	0.79	1.15	1.32	1.41

The distribution of all judgments is shown by the following per cents:

14.6	18.4	21.6	45.4

Thus almost half of the aggregate of judgments was "Wholly Uncertain."

The distribution of judgments over the various grades of certainty varied some between the first and final tests for all reagents. This was caused by variability in the direction and extent of the attention, owing to the difficulty of carrying out the instructions to attend to the whole card; only one reagent (Rt.) was able to do this consistently and he complained that the unnatural effort was a distraction. It has not been stated, perhaps, that all the letters on the card in all our tachistoscopic tests fall easily within the angle of acute vision. The effect of narrowing the attention to a portion of the card was to get a few letters in great clearness at the expense of any imagery

of the rest of the card however vague, to increase the number of "Certain" choices, and to decrease the influence of 'fringe' imagery in determining R cases in "Uncertain" choices.

That the latter influence was present is indicated by the time-relations between the right and wrong cases in Uncertain choices: If the four averages containing the greatest increase in time of R over W cases, the four containing the least increase, and the five containing decrease in time, are selected and compared, we get the following table:

Increase in time	.54",	Ratio	R:W	1.40
" " "	.125",	"	"	.93
Decrease " "	.14",	"	"	.83

Which indicates that in "Uncertain" choices time was a function of R cases. It should be noted that when R cases are not influenced by 'fringe' imagery, the ratio of R:W should be 1., and that the table shows in the ratios of lower value an opposing influence which will be discussed later as the effect of preceding impressions. In "Certain" choices, of course, R cases correlate with less time.

Variation between reagents in extent of the card attended to is indicated by the location of letters in "Certain" choices: 1st line, Hhs.; 1st and 2d line, Hs., Rt., Wn.2, Ck.; 1st and 2d mainly, Al; 3 lines, Br., Wn.1.

The averages emphasize three types:

	Lines		
	1	2	3
Hhs.	24	2	1
Hs., Wn., Rt., Ck.	14	10	3
Al., Br.	9	19	8

Other factors of variation in the processes involved especially in "Uncertain" choices, as shown by quantitative analysis, are the influences of favorite letters, of similar letters, of the position of the letters exhibited for choice, and of preceding letters.

All of the reagents favored or ignored particular letters, although these letters rarely retained their special status throughout both tests, but rarely exchanged their status in the final test. This influence is verified by the fact that choice of the favorite

letter is made in shorter time, besides being shown by greater frequency in a tabulation of all letters chosen.

Partiality for the left or right letter exhibited for choice was shown by all reagents and is constant for both tests; in five cases it was as high as 1 : 2.

Influence of preceding letters was suspected when it was noted that wrong cases would frequently have been right for preceding cards, and was found by comparing the number of identical letters preceding the *recorded* letter with the number preceding the *true* letter. The aggregate shows the influence clearly:

	Preceding cards		
	1st	2d	3d
Certain choices	27.8%	5.3%	1.5%
Uncertain choices	9.4%	45.0%	-6.5%

This influence upon "Certain" choices was shown only by space error, and must have been effective through facilitating perception;[181] upon "Uncertain" choices it was shown by both space error in R cases and by W cases, and must have been effective, in the former, by augmenting 'fringe' imagery into determining influence, in the latter, by either augmenting 'fringe' imagery of a similar letter, or by persisting to the exclusion of 'fringe' imagery from the last perception.[182]

A factor working for wrong cases, especially in "Not just certain" choices, and counteracting the influence of preceding letters toward R cases in "Uncertain" choices, was the influence of similar letters. All errors in "Certain" choices were attribut-

[181] Schumann (Die Erkennung von Buchstaben und Worten bei momentaren Beleuchtung. Bericht u.d. I. Kongress f. Exp. Psychol., 1904: 36) inferred from the fact that the recognized letters were not always those most clearly seen, that the recognition of letters must be assisted by residua of previous perceptions of them.

[182] In tachistoscopic presentation of mutilated typewritten words, Pillsbury (A study in apperception. Am. Jr. Psychol., 1896-7, 8: 355, 357, 359) found an unconscious effect of preceding words upon the word-completion process; introspective report of the absence of an association determining the completion was untrustworthy. McComas (Some types of attention. Psych. Rev. Mon., 1911, No. 55, p. 33) also found, in tachistoscopic work, a determining influence from presentations given 2 min. and 5 min. earlier; content appeared to lie dormant until reported as seen on a later card.

able to this cause, and revealed as similar letters, TH, MW, DB, XK, NY, RB, PR, NK, CQ, YV, BK.

In testing for the influence of training in the reproduction of imagery upon this test we cannot use the gross scores of R cases; increase of reproduction is consistent with an increase of W cases in "Not just certain" choices because of the similarity of letters; we are consequently limited to the "Uncertain" choices, and, although they are influenced as shown above by many factors of variation, they furnish evidence that the training produced some effect.

Since the range of initial capacity was but from 43% to 50%, results may be grouped and handled with a degree of confidence. The regular reagents show a greater increase in R cases:

	First	Final	Difference
Regular	44.8%	58.1%	+13.3
Control	45.9%	50.0%	+ 4.1

Part of this increase must be due to the 'maturing' of 'fringe' imagery as is indicated by the greater increase in the time of the R over the W cases in the final test:

First test	.04"
Final test	.25"

It was pointed out above that time here is a function of R cases. This increase is not shared by the control reagents nor by one of the regular reagents (Wn.) who in her training avoided reproduction of simple imagery.

Since there was some increase of influence of preceding letters, it is possible that this influence tended, more than in the case of the control reagents, to augment the 'fringe' imagery of the last presentation in a way similar to the effect of this influence in facilitating perception in cases of "Certain" choices. If the 'fringe' material from preceding cards is not 'matured' about a nucleus of 'fringe' imagery from the last presentation, its influence would be toward W cases; and the above table indicates by per cents below probability (50%) that this occurred in the work of both groups in the first test, and it may have occurred and have been overcome by its opposing factor in the

final test. That this balance occurred in the case of the control reagents seems evident from the slight increase in the per cent of R cases, as is shown by the table above, in spite of great increase in the amount of influence from preceding cards:

	First	Final	Difference
Regular	13.3%	16.7%	+ 3.4
Control	18.2%	32.5%	+14.3

This table also shows that the control reagents were somewhat more influenced by preceding letters than were the regular reagents in the first test. The effect of the interval upon the control reagents was to shift this influence toward the more remote cards and to make it independent of imagery from the last presentation. The effect of the training upon Hs. and Rt. was to shift this influence to the more recent cards and to combine it with 'fringe' imagery of the last presentation.

(2) *Reproduction and Recognition of Letters*[188]

The results of this test furnish another forceful illustration of the worthlessness of merely quantitative treatment of 'mental tests.'

Initial capacity in recording letters from a 12-letter-rectangle exhibited 0.1″ ranged from 4.15 to 10.05 points. The three regular reagents occupy the three higher places. With one exception gains in the final test vary inversely with initial capacity. The final capacity of but one control reagent exceeded the lowest initial capacity of the regular reagents, and that exceeded by 40% the final capacities of two reagents who trained, in the preceding experiment, on this work for 18 days. Introspections offer no explanation.

The recognition part of the experiment, designed to test for reproductive tendencies too weak to reach the threshold,

[188] Experimental work justifying our selection of this test has been done by Robert Mac Dougall (Recognition and recall. Jr. Philos. Psych. & Sci. Meth. 1904, 1: 229-233) who used words for his material. He found that where about a half were reproduced through recall, about three-fourths were recognized. "Characteristic differences between recall and recognition," have been more recently studied by Hollingworth (Am. Jr. Psych. 1913, 24: 532-544).

was ill advised owing to the impossibility of checking reagents in their recognition and of equating their scores.

Two important facts, however, may be extracted from the results.

The regular reagent who avoided reproduction of simple imagery in her training and who was not benefited by the 'maturing' of the 'fringe' imagery in "Undecided" choices in the preceding test (Wn.) lost 6.2% while the other two regular reagents gained 7% and 5% respectively, yet her initial capacity was slightly below their's.

And the introspective evidence of variability in processes recorded in Test 17 of the preceding experiment is supplemented by similar evidence showing that this variability appears in each 'moment' of the experiment; particularly in four of the five intervals into which the experiment naturally falls: (1) In the 'Anlage' between "Ready" and the stimulus; (2) In the direction and distribution of the attention during the perception, especially with reference to the treatment of the after-image which persists after the screen has fallen; (3) In the process during the voluntary interval between perception and recording; (4) In the process of coördinating the maturing, retaining, and reproducing part-processes, during recording.

(3) *Sound Discrimination*

It will be remembered that the work of this test is the same in kind as the work of the training, the only difference being that here the sound-pendulum was used instead of the fall-phonometer (*i.e.*, the sounds were produced with wood instead of with steel), and the time-intervals between stimuli were all short (about 3″).

(a) Processes

Reagents were not shown the sound-pendulum or the manner of producing the sounds, in order to avoid the 'stimulus error' and the complication of visual imagery. But usually curiosity was evinced as to how the sounds were produced,

and in almost all cases visual imagery of imaginary apparatus was frequent in the process of discrimination.

Hs. used auditory imagery for judging, and in both tests speaks of comparing the images; in the second test she speaks of ease of judging in one series because the auditory image of the first stimulus remained in her mind without effort. But in the beginning of the second test she also compared the image of the first with the sensation of the second stimulus, only bringing the latter into imagery for comparison when the judgment was at first doubtful. She was helped by kinaesthetic imagery into which the stimuli were converted by singing the tone, by striking or pressing down or weighing with her arms and hands, etc. When the kinaesthetic and auditory bases of judgment conflicted she speaks of following the latter. She had considerable visual imagery which was regarded as a hindrance: of the experimenter holding a hammer and knocking on the table, of a scale for distributing intensities,[184] and of steel balls falling. Another distraction was the anticipation of the second stimulus. An affective image, as of knocking in the back of the head, is spoken of at the beginning of the first test; and an auditory image of her own voice singing the stimulus occurred in the second. The interval of training seems to have diminished the visual imagery and other distractions, leaving her with the general method of holding the auditory image of the first stimulus as a basis of judgment upon the impression of the second or of comparing with the image of the second in case the difference seemed doubtful.

Wn. also has varied imagery as bases of judgment; but her kinaesthetic imagery is perhaps predominant, affective imagery following, then visual and auditory. She speaks several times in her introspections in the first test, of comparing images; sometimes these are a combination of auditory and kinaesthetic; and in case of doubt she reviews them over and over in her mind. Her kinaesthetic imagery began immediately and continued throughout: She tried to remember by kinaesthetic

[184] *Cf.* Angell, F.: Phil. Studien. 1892. 7:414-468.

image in the mouth, head and arms (1 : 1), pressed the teeth together (1 : 2), tried to sing the stimuli (1 :3, 2 :7), nodded head (1 :10); and several times the stimulus could be recalled only through kinaesthetic imagery (1 : 6, 7). She had affective imagery: felt knocks in the head (1 : 1), "feel the sound before I hear it; if 'feel' and 'sound' do not agree I make both intensities with my arms; this aids my judgment more than auditory images" (1 :5). Distracting influences were the visual imagery of woodpeckers and trees (1 :1), of E with a little wooden peg (1 :2) or hammer (1 :4), of toy men hammering a block (though she thought this helped) (1 :6); anticipation of the second stimulus (1 :3); bothering about the instrument (1 :3); bothered because of so many "greater" judgments (1 :8) or "less" judgments (2 :7). The interval of training seems to have qualified her to give judgment upon the second impression; she says she compared auditory image with auditory impression (2 :1). Her kinaesthetic imagery continues, moving hand as if it held the hammer (2 :7); and so does the affective: "feel the little hammer in my head and myself knocking with it" (2 :2). The visual imagery does not seem quite so frequent. Although the interval was not over a few seconds, she felt that she makes the sounds more and more alike as she recalls them (2 :6), which indicates that voluntary strengthening of the first stimulus may account for her type which was shown in her training results.

Rt. from the first protested that he carried no image of the first stimulus over to the second (1 :1, 3); but that he "rethinks" if not "re-images" it (1 :1). When he thinks "just how loud was that sound?" and dwells upon its intensity, he becomes confused in his judgment upon the second (1 :4). An attentive attitude less than maximum was most satisfactory (1 :3, 4, 5). The probability of a symbol of opposite meaning following several like symbols in succession in a series, he thinks, may have occasionally influenced his judgment in doubtful cases (1 :7). In both tests he was bothered by rhythm which would run through his head and tend to make the second

stimulus louder or weaker than it really was (1:8, 9; 2:4). The effect of the training was to make these 'wooden' sounds seem "novel"; he was very uncertain of his judgment in the first series of the second test, and his score was low. But in his 3d series he underscored four out of his nine judgments, showing that confidence soon returned. And near the end of the test he says: "The whole of the work today is so much easier to follow, with the short [temporal] interval [between the stimuli] (2:8).

Al. thinks that she compares impressions that seem to be in her head, in making judgment (1:1); she attentively fixes the first and waits a few moments after the second stimulus has been received before judging. But by the middle of the first test she remarks that it does not take so long to judge (1:5); even then, the first sound seemed to be an impression in her head. After the interval the clear differences were judged upon the receipt of the second stimulus; the smaller differences, after a few seconds of comparison (2:1-3). Later in the test she felt the effect of practice (2:4, 6) when the differences were clearer and judgment was more readily given. The second test seemed much easier.

Hhs. made judgment immediately upon hearing the second stimulus; seems to have classified his sounds as light, medium, harder, (as of striking a board) (1:7, 2:4) and also without using the class-names (2:8-10). He had visual imagery of a metronome (1:6), and of some one striking a board with a small mallet. Thinks the second test a little easier, and that there were more clear intervals in it. Shows considerable practice-effect in the first test: 3, 3, 1, 4, 3, 5, 5, 5, 5, 6.

Br. uses as a basis for judgment the effect the sound works upon him (1; 2:1). To this he added a sort of a classification. The second test seemed much easier than the first; more clear differences.

Ty. thinks she compares auditory images, at first (1:1), which when clearly different are outside (1:4), but when not, they are brought inside the body and converted into a "tactual"

image in the eyes and nose (1:4). She has some kinaesthetic imagery in the arm as if striking (1:4, 2:3). After the interval there is some change: she weights the after-images of the stimuli, if their difference is slight, in her ear (2:2); and has kinaesthetic images in ear and throat (2:6) and chest in breathing (2:6); sometimes of humming the stimulus (2:6) or tapping it; and feels that the after-image of the second stimulus is louder than it should be (2:5); the change in general was toward kinaesthetic and possibly affective (tension in the ear) conversion.

Dn. says that in comparing sounds his "mind was concentrated on a point inside the ear" (1:2); he compared controlled exhalations of his breath, like carrying the tone of a piano in the roof of the mouth; less intensity, smaller volume of breath breathed out. He also classified sometimes. In the second test the same method was continued, except that in breathing the tone the tension of the throat muscles was taken into account; and it was supplemented by kinaesthetic imagery of the head and arms as in nodding or striking; of the toes, as pressing down for a heavy tone, raising for light (perhaps transferred from piano-playing).

These analyses indicate clearly that for the unskilled reagent discrimination of intensities of sound is a very variable process. Practice may not lead to improvement, as was shown by our trained reagents, and is verified here by Ty. and Dn., and the chief causes of retrogression are indirect methods of dealing with the stimuli; Wn, Ty., and Dn. are the clearest examples of this.

A point of interest is that the 'wooden' sounds caused the trained reagents some interference after their habituation to the 'metallic' sounds of the training: Rt. recorded that these sounds seemed "novel" and he was consequently very uncertain in his judgments, in the beginning of the second test; and the sum of R cases in the first two series in the final test was lower for each of the three reagents than in the corresponding series in the first test. By the third series, however, the interference had been overcome.

(b) Scores

Initial capacity ranged from 48.8% to 76.3% R cases. The three regular reagents occupy the three higher places, and their scores in the final test change in a way consistent with the results of their training: Hs. and Wn., who lost consistently in their training, lost here; Hs. owing to conditions of health, and to her extraordinary score in the first test; Wn. to the development of the inadequate method of classification and association which prevented treatment of the stimuli in terms of simple auditory or kinaesthetic imagery. Rt., who, although he showed loss in the latter part of his training yet showed gain in the intermediate part, made a slight gain. Thus the training effect shows itself in this test.

The control reagents whose initial capacity was nearly as high as that of Wn. and Rt. also lost, Dn. losing the greatest amount owing to the development of an indirect kinaesthetic method which was not so trustworthy as his earlier method of basing judgment upon 'affects' or more direct kinaesthetic imagery. The detrimental effect of an indirect method of discrimination has already been pointed out.

(4) *Memory for Visual Symbols*

(a) Processes

In general all reagents were more or less helpless at the beginning of this test because the symbols were strange and evaded fixing. Almost all avoided the pure visual effort for which the test was designed;[185] they compared the symbols

[185] In this respect they conform with the work of Ebert and Meumann's (*op. cit.*, pp. 50, 116) reagents, who declared that the symbols could not be learned from the pure visual impressions. Kuhlmann (On the analysis of the memory consciousness, a study in the mental imagery and memory of meaningless forms. Psych. Rev., 13:342) also found indirect methods of memorizing largely employed: associations, verbal descriptions, motor tendencies of eye and hand. And in another place (Problems in the analysis of memory consciousness. Jr. Philos. Psych. & Sci. Meth. 1907, 4:5-6) he points out a more subtle mode of vicarious functioning; through the more or less extended organic reactions which are evoked by any sensory stimulus,

with conventional characters and things, gave them the names of these associated characters and things, and remembered the names, usually at first without the support of visual imagery necessary to record correctly.

Owing to the inexperience of the control reagents in introspection but little knowledge is at hand of their processes; though that little points to a freer use of visual imagery and visual association of the forms of the symbols, than was true with the trained reagents.

1) Immediate Memory

The process of introspecting after recording from the single presentation of six symbols was difficult, and the processes of perception and reproduction were very imperfectly revealed. There was sufficient evidence, however, to indicate that there was large individual variation.

For the 'note' forms, the effort was a) to visualize the presentation (Hs.), b) to transpose the content into a visual scheme using the musical staff (Wn.), or c) to classify the flags according to spatial relations (Rt.).

For the 'sickle' forms, the effort was generally verbal, to name conventional characters to which the symbols were similar, and to reproduce from kinaesthetic-auditory imagery.

2) Complete Learning

The trained reagents show clearly in their introspections that the processes employed in the 'complete learning' are quite complex and variable.

For the 'note' forms there were three methods of learning employed: a) Naming the number and positions of the flags in the consecutive symbols, for recall in verbal imagery (Hs., Wn., Hhs.); b) classifying the symbols according to the number of flags, and their relations of symmetry, counting the symbols to identify related symbols by number, for recall in mixed imagery largely visual (Rt., Br., Hd.); c) combination

the lack of prominence of which in consciousness is no criterion of their utility. Bentley's statement that the aids to complete recollection may become the real vehicle of retention, has already been referred to (foot-note, p. 190).

of naming and classifying (Al., Hn.). With methods a) and c) a few symbols at the beginning and the end of the series were usually held in pure visual imagery. The fact that the learning of this series may involve very different kinds of work is illustrated by reagents employing methods a) and b) respectively: a) Hs. learned the series by naming, 1. lower, middle, 2. middle top, 3. one middle, 4. two middle, 5. two bottom; etc. It was a straightforward 'rote' method, converting the presentation into verbal imagery; this was made vivid by verbal repetition, and was recalled through kinaesthetic-auditory imagery, supported by visual memory. Wn. also named but used slightly different terms, adding left and right, and supported her verbal imagery with kinaesthetic imagery of direction in neck and arm. b) Rt. used the early presentations for inspecting the symbols and seeking relations in the position of the flags; then he began counting the symbols as they passed the window and fixing related pairs: No. 7 is No. 1 inverted, 6 is 12 reversed, 9 is 1 with flags at half-mast, etc.; and by drawing the symbol in the air with his pen while cognizing it and repeating the number, he formed associations between pen-movement for reproduction and the number of the symbol; reproduction was supported by visual imagery. This was a more logical method, involving the apperception of relations.

For the 'sickle' forms, the same three kinds of methods were used, and with two exceptions the reagents carried over the methods they had used with the 'note' forms: a) the symbols were named by calling them h, ?, ? inverted, wrong v, right v, y inverted, g, 5, etc., and in reproduction the kinaesthetic-auditory imagery was supported by visual imagery (Hs., Wn.); b) the symbols were classified according to form (Rt.); or c) were learned by classifying some and naming others (Al., Hd.). Hhs. used method a) in his first test and b) in his final; and Hd., who used method b) with the 'note' forms, used method c) here.

In the final test methods usually continued without much change, except on the part of three control reagents: Br. changed

to a more purely visual method, Hn. from more purely visual to naming and visual, and Hd. introduced a method of counting and fixing forms in their positions (the method Rt. used in both tests).

The effect of the interval was to make the test easier for all reagents; this was so marked that a third of them assumed that the series of the final test was identical with that of the first, and felt a strong recognition for some of the sequences. The principal factors contributing to this were: (a) Familiarity with the symbols, b) concrete knowledge of the demands of the test, c) possession of a method, d) in some cases an improvement in method.

(b) Scores

If increase in facility of reproduction of imagery can be shown at all, it must appear in increased scores. In some cases, however, the scores are affected by change in method and are unreliable as measures of reproductivity; and in all cases, presumably, there was some improvement in the application of method leading to more adequate impression of the stimulus, which cannot be separated from the factor of reproductivity in the scores.

1) Immediate Memory

Since the tests in 'immediate memory' were necessarily short, incidental causes of variation, including direction and distribution of attention, must play a correspondingly large rôle. And since it happens that all of the control reagents, except possibly Hn., worked more freely with visual imagery than did the more mature regular reagents, they probably received more benefit from the practice-effect of the test, and this advantage might more than off-set a slight increase in reproductivity brought by the regular reagents from their training.

Individual variation in initial efficiency, for the 'note' forms, ranged from 0 to .329 (1 representing a perfect score), and for the 'sickle' forms, from .080 to .414. Per cent of improvement was reckoned upon the final score and is too irregular to make

the examination of the tables profitable. It ranged, for the 'note' forms, from 25 per cent loss to 100 per cent gain, and the control reagents show the best gains; for the 'sickle' forms, from 0 to 81 per cent; neither group of reagents shows advantage over the other. Several scores are of interest: Wn.'s great improvement in the test on 'note' forms was due to a change of method from the use of the musical staff to naming; Hhs.'s 0 score in his first test was due to inverting each of the two symbols he retained (visually); Rt.'s large improvement on the 'sickle' forms was owing to greater facility in classification. The greatest and most consistent gain on both forms was made by Hd., shown later to be a special case, indicating that training in memorizing 'literal'[186] prose increased efficiency in this test.

2) Complete Learning

The 'complete learning' enabled the reagent to collect himself and work out a method in the course of the first test; and the variation in the factors of attention and adaptation was not so potent a source of error.

Initial efficiency ranged, for the 'note' forms, from 15 to 31.3 presentations, for the 'sickle' forms, from 12.3 to 42.8 presentations. The trained reagents took, in general, fewer presentations than did the control reagents.

Improvement was reckoned in per cent. of initial efficiency:

	Regular			1st Control			2d Control		
'Note' forms	Hs.	(15)	53.3						
	Wn.	(16)	46.3						
				Al.	(19.6)	53.1			
	Rt.	(23)	52.2	Br.	(24)	20.8	*Hd.	(25.6)	45.2
							Hn.	(26.2)	39.9
				Hhs.	(31.3)	42.5			
'Sickle' forms	Hs.	(12.3)	50.4						
				Hhs.	(24)	19.2	*Hd.	(25.2)	64.3
	Wn.	(29.1)	52.9						
	Rt.	(42.8)	50.9						

The number in parenthesis shows initial capacity in number of presentations; reagents are ranged according to initial capacity.

*Hd. is shown later to be a special case.

186 In 'literal' prose the learning must be 'word perfect'; which contrasts with 'substance' prose, in which reproduction of ideas is tested.

Since initial capacity of the regular reagents was higher than that of the control reagents, they could scarcely be expected to show as much improvement unless there was a relatively greater increase of capacity in reproduction; the fact that they show greater improvement than four control reagents out of five, therefore, seems good evidence of a definite advantage. Averages indicate this advantage still more clearly:

	Note	Sickle
Trained	50.6%	51.4%
Control	38.8%	

The trained reagents were somewhat more accurate in their reproductions: In the first test two out of six records were without error, as against one out of five by the control group; and in the final test they made four out of six without error, as against three out of six by the control group.

One of the control reagents, Hd., was withdrawn from his group in the consideration of results, because he represents an exception; he had been given a rather severe course of training in 'literal' prose by his fraternity brothers just before the final tests. And although literal memorizing is hard for him, and he left the room after the first test tired out, he found the final test unexpectedly easy, made the two reproductions without error (both scores in the first test were imperfect: .937, .833), and reduced presentations 45.2% and 64.3%. There is no doubt about the influence of his prose training upon this test.

A negative 'spread of training' seems to be indicated by Rt.'s results in the first test in 'complete learning.' His method was that of classification and grouping, and introspections show that his habit of disregarding the stem in the 'note' forms, which was invariable, was carried over to the 'sickle' forms, where both stem and curve were variable, and caused confusion; he learned the 'note' forms in 23 presentations, while it took 42.8 presentations to learn the 'sickle' forms. Not all of this difference, however, should be attributed to negative spread of training, for the 'sickle' forms are more difficult to classify and group than are the 'note' forms.[187]

[187] Though not necessarily more difficult to learn by naming, as is shown by the initial capacities of Hs.

(c) Summary

The process of memorizing visual symbols did not engage much visual imagery; the usual method was to associate the symbol with some familiar thing and remember it by verbal-motor imagery of the name of that thing, or to classify the symbols for reproduction from logical memory. Visual perception served principally to analyze and interpret the symbol for conversion into verbal-motor terms or to effect classification. Where visual imagery was used, it supported the more prominent kinaesthetic-auditory. The complete process utilized a combination of verbal-motor, kinaesthetic, visual, and auditory imagery.

The scores of the 'complete learning' show that although the control reagents began with less efficiency and therefore might be expected to make greater gain than the trained reagents, the latter, and one of the control reagents who had training in memorizing literal prose, made more improvement. The only explanation at hand is that training in retaining and recalling imagery occasioned by intensities of sound contributed to facility in retaining and recalling the combined imagery used in this test.

e. Conclusion

The results of this experiment supplement those of the Experiment on Attention in illustrating the variability in processes engaged upon a simple task and in locating the variability in each of the successive 'moments' of a test.

Although the training, with its evident retention and reproduction of auditory and other imagery, did not result in improvement in sound discrimination, analysis of processes used in the training shows change in those processes, and training-effect shows itself in the tests.

In Test 1. (Recognition or Choice of One of Two Letters) the regular reagents increased R cases in 'uncertain' choices due to more 'maturing' of 'fringe' imagery of the last presentation and to strengthening this process by uniting to it the influence of preceding identical letters.

In Test 2. (Reproduction and Recognition of Letters) the

anomalous results emphasize the worthlessness of purely quantitative treatment of the results of 'mental tests.'

In Test 3. (Sound Discrimination) the results of the regular reagents are consistent with those of their training on similar material; but habituation to the 'metalic' sounds in the training caused interference with the transference of practice-effect in the early series with the 'wooden' sounds of the test. The greatest loss, by a control reagent, illustrates the detrimental effect of an indirect method of discrimination, thus agreeing with the training results of Wn.

In Test 4. (Memory of Visual Symbols) the trained reagents show their advantage, in 'complete learning,' over the control reagents, except in the case of Hd. whose large and consistent gains in both 'immediate memory' and 'complete learning' indicate clearly that his inter-test training in memorizing literal prose contributed to his facility in memorizing these symbols.

One of the corroborating facts in the results is that the regular reagent (Wn.) who avoided using simple imagery in her training showed less gain in Test 1. and a loss in Tests 2. and 3., where simple imagery was requisite, but was not handicapped in the 'complete learning' of Test 4., where the imagery could be more complex.

It is noteworthy that all the gross quantitative results of Tests 1, 2, 3, and of 'immediate memory' in Test 4, were worthless; only by careful analysis of scores and introspections was the fact of 'spread of training' made evident at all.

The chief contribution of the experiment is: That the specific training did not result in gain in efficiency with the training material, but that it did result in changes in the processes it engaged and it showed its 'general' character in influencing the processes involved in Recognition or Choice of One of Two Letters (Test 1) and in 'Complete Learning' of visual symbols (Test 4) both of which differed radically from the training in sense-mode of impressions and in methods of work.

Facts of this character, already noticed, in the Experiment on Attention, in the failure of Al. to improve after his third day of training (p. 93), and in the failure of Rt. and Sl. in their

effort to apply the method of learning developed in their training to commercial signs (p. 154), indicate that not only is there general effect of special practice, both negative and positive, but there is an occasional negative special effect of special practice: Changes in the mental processes incidental (1) to the greater complexity of the processes involved in the next step of progress, (2) to the conscious application of a method already automatic, (3) to the development of a method which neglects the essential process, (4) to change of attitude toward the experiment, or (5) to chance variation in the processes, may cause retrogression in efficiency, indicated by a drop in the practice-curve. It is well known that in continuous practice the scores on the immediately following days suffer from this retrogression. Retrogressive effect of special practice must therefore be taken into account in testing for general effect. This negative special effect shows itself in negative general effect in tests similar to the training, and is not inconsistent with positive general effect in tests less similar to the training.[188]

3. Critique of the Test-Training-Test Type of Experiment

Much has already been said by way of a critique upon the Test-Training-Test type of experiment in the introduction to The Experiment on Attention (pp. 65-70) and under the headings of Extent and Variability (pp. 167ff) and The Practice Curve (pp. 173ff), in the same experiment, as well as throughout the text in the discussion of The Test Results; but it seems desirable to bring the critique together into a plain statement unencumbered with the concrete evidences upon which it is based, and to illustrate with a clear hypothetical case.

The prime requisites of this type of experiment are (1) that the tests shall afford a reliable measurement of a known process or group of processes, (2) that the training-effect shall not only be measurable but shall be capable of definite description in terms of changes in processes, and (3) that change in efficiency in the

[188] In this respect it resembles 'interference,' which, however, is more transient.

final test shall be described with sufficient precision to indicate its dependence upon, or independence of, the training-effect. Only when these requirements are met can the functional relationship of mental processes of various kinds be determined with certainty.

In order that the processes tested can be known, trustworthy introspection is essential. If it is dispensed with, or if it is faulty, the test-averages may not belong to the same denomination, in which case they can be neither grouped nor compared for any intelligible purpose.

Suppose that the capacity of the reagents K., L., M., N., and P. to progress from station A. to station B. is measured by a test; that K. and L. are trained in progressing from R. to S.; and all are again given the test from A. to B., for the purpose of determining the training-effect upon the capacity of K. and L. Suppose progression in this illustration is made by travel, and in the first test K., N., and P. walk, and L. and M. ride bicycles; in the training K. and L. both walk; and in the final test K. and P. walk, L. and M. ride bicycles, and N. takes an automobile. Let the following table show the results, in minutes:

			Regular		Control		
			K.	L.	M.	N.	P.
Training	Beginning		125	130			
	End		95	100			
Tests		First	125	20	25	135	125
		Final	100	22	20	9	120
	Difference		—25	+2	—5	—126	—5
	Average		—11.5		—45		

Conclusion: Results show that training in progression from R to S. has a negative influence upon capacity to progress from A. to B., since the practice-effect of the first test upon the final (-45) greatly exceeded the gain (-11.5) made by the trained men.

Analysis of processes, however, shows that training-effect was transferred by K.; he used the same processes, as affected by practice, in the final that he did in his first test and in his train-

ing. A negative effect is shown by L., since his practice in walking caused his bicycling muscles to retrograde. The anomalous gain of N. is the result of a radical change in processes, independent of the purpose of the test. For accurate knowledge of the reliability of the test-results other conditions affecting the progress should be known: whether the traveler had to turn out of the road into rough footing to pass vehicles, whether any part of the road was slippery, owing to the sprinkling cart or rains, whether any unusual conditions affected the work. In other words, the conditions must be under the control of the experimenter or must be known in order to be reckoned with; and in mental tests these conditions are both objective and subjective.

This illustration represents the facts all too accurately for the comfort of those of us who have employed this type of experiment, and have struggled with anomalous results. Merely quantitative treatment is worthless. Incidentally, it is difficult to see how any method of statistical correlation can improve upon the simple treatment shown above; and it is equally difficult to imagine a value for even the single test averages: *e.g.*, what can we know by finding that the average initial efficiency in progressing from A. to B. is 86 minutes, when no single ability or group of abilities approached that measurement?

It seems patent that results from great numbers of reagents cannot be more reliable, when different kinds of work are measured; this sort of error will not cancel itself out by multiplying it, nor will the 'probable error' have any meaning as an indication of the reliability of the measurement.

Practically, the requisite for introspective description of processes limits the number of reagents. The security of greater numbers may be obtained by repetition of the whole experiment.

The requirement that the test shall afford a reliable measurement is not easily met, for the reason that it must be arbitrarily decided as to how much practice-effect to include. The usual preliminary series which gives an opportunity for adaptation to the work of the test does not remove the difficulty; practice-

effect continues and at various rates with different reagents,[139] especially if different methods of work are employed. In almost any case a single test score is bound to be unreliable; in some of our tests in the Experiment on Attention averages of five series,

[139] Otis and Davidson (The reliability of standard scores in adding ability. Ele. School Teacher, 1912, 13:91-105) found different types of learning ability among 202 8th-grade children who were given 25 tests in adding; amount of improvement, moreover, bore no constant relation to initial efficiency. Wells (The relation of practice to individual differences. Am. Jr. Psych., 1912, 23:75-88) who trained 10 adult subjects 30 days on adding and marking out zeros, concluded that "A superior performance at the beginning of special practice is not necessarily, nor even probably, attained at the sacrifice of prospects for further improvement. A high initial efficiency may carry with it as much or more prospect of improvement under special practice than a low one. . . . Not practice, but practiceability, is responsible for the superior position of such an individual" (p. 88); if the individual's high efficiency is the result of greater practice, his position may be near the "physiological limit" or end of his practice-curve, and practice-effect may be expected to be small; if it is the product of greater ability (native endowment), his position is nearer the beginning of his practice-curve and practice-effect may be expected to be large (p. 75).

That the reagent with the higher initial ability improves more in practice was found in tests in tapping by Bolton (Relation of motor power to intelligence. Am. Jr. Psych., 1903, 14:621), in discriminative reaction on a typewriter by Culler (Interference and adaptability. Archives of Psych., 1912, 3: No. 24, p. 57), in marking out zeros by Wells (*op. cit.* p. 79ff), in adding by Wells (*op. cit.*) and Hahn and Thorndike (Some results of practice in addition under school conditions. Jr. Ed. Psych., 1914, 5:79), and in multiplication by Thorndike (Effect of practice in a case of a purely intellectual function. Am. Jr. Psych., 1908, 19:374ff).

That the reagent with the lower initial ability improves more in practice was found in training in learning non-sense syllables by Müller und Schumann (Experimentelle Beiträge zur Untersuchung des Gedächtnisses. Zeits. f. Psych., 1894, 6:328) and von Sybel (Ueber das Zusammenwirken verschiedener Sinnesgebiete bei Gedächtnisleistungen. Zeits. f. Psych., 1909, 53:356), in marking out letters by Binet (Attention et Adaptation. Année Psych., 1899, 6:368), in free associations by Wells (Practice effect in free associations. Am. Jr. Psych., 1911, 22:2-3), and in adding by Thorndike (Practice in the case of addition. Am. Jr. Psych., 1910, 21:485).

Hollingworth (Individual differences before, during, and after practice. Psych. Rev., 1914. 21:1-8), who followed Whitley and Wells in attacking the problem directly, gave 175 repetitions of seven tests to 13 adult reagents, and calculated the coëfficients of correlation between the orders of abilities in the 1st, 5th, 25th, 50th, 80th and 130th trials and the last trial. The averages

taken on two days, were unreliable. The averages used in our Experiment on Sensible Discrimination were much more reliable, and they involved the work of three days, about forty-five minutes each. In reaction, discrimination, and tachistoscopic tests it should probably extend to at least 100 experiments.

The number of tests should also be limited on account of inter-test practice-effect, although this source of error may be partly eliminated by arranging the series composing the tests in 'double fatigue order';[140] successive tests may be made equivalent in difficulty by using Müller's 'cyclical changes' ("Zyklischen Wechsels").[141]

The training should perhaps be longer than is usual, and as rigorous as circumstances will permit, say six months for such work as cannot be trained to maximal efficiency in less time.

The control reagents should equal the trained reagents in

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of these coëfficients were .41, .61, .73, .77, .85, and .92, indicating a gradual approximation, through these various levels of practice, to the final order, and, consequently, the insecurity of the results of the early levels as indicative of the final relative capacities of the individuals tested. In adding and in cancellation of digits the coëfficient of $r = +.75$ was not reached until the 25th trial; in tapping, the 130th trial; but in naming colors and in coördination (aiming) it was reached by the 5th trial.

An indication of change in processes during practice, which had the effect of diminishing individual differences, is to be found in the coëfficients of correlation between tests at varying stages of practice published by Winch (Jr. of Philos. Psych. and Sci. Methods, 1911, 8: 377) and Hollingworth (Correlation of abilities as affected by practice. Jr. Ed. Psych., 1913, 4: 405ff); Hollingworth found the coëfficients (averaged for his seven tests with 13 observers) for the 1st, 5th, 25th, 80th, and 205th trials to be .065, .280, .320, .390, and .490, respectively.

That differences in rate or amount of improvement in practice may be dependent upon differences in mental processes is shown by McMein and Washburn (Effect of mental type on the interference of motor habits. Am. Jr. Psych., 1909, 20: 282ff) who found that reagents who used visual imagery freely made more rapid improvement in card-sorting, and overcame interference, produced by turning the compartment-scheme through 180°, more easily, than the other reagents. And von Sybel (Zeits. f. Psych., 53:356) found that the practice-effect was greater for reagents with the less initial facility in method of learning.

[140] As was done by Fracker: *op. cit.* p. 63.

[141] *Vid.* Müller: Zeits. f. Psych., 1905, 39: 116.

number, in initial efficiency, and in facility in introspection, or their results may not be comparable with those of the trained reagents. If these conditions are met, comparison, both qualitative and quantitative, may be intelligently made; and the simplest mathematical treatment would seem the least objectionable, even the per cent form of expression being serviceable.[142]

Finally, two more criticisms with reference to the interpretation of difference-scores, are important: (1) An exceptionally large difference-score is a symptom of radical change in kind of work and calls for individual treatment; (2) A small difference-score does not necessarily mean that training-effect is absent; it may merely be the resultant of positive and negative factors in that effect. In either case introspective description of processes must, when possible, furnish the chief grounds for interpretation.

4. Analysis of the 'Common Factor'

It is generally agreed that 'the Ccmmon Factor' is responsible for the general effect of special practice; but as to what it is or may be, there is difference of opinion. It is interesting to note that its nature is growing more complex as experiment and discussion advance. In the early days it was regarded as largely physiological and related simply and immediately to the data of presentation, or, as mental habit, related definitely to the method of the experiment; in marking out words, for example, it was said to consist principally in eye-movement, pen-manipulation, and in the habit of looking for the least common letter. And

[142] The chief objection to the per cent form of expression involves the presumption of a direct comparison of measurements of improvement made by reagents who differ widely in initial efficiency, (*vid.* Whitley's hypothetical case showing how varying methods of portraying practice-effect lead to varying conclusions, *op. cit.* 100-105) or who differ widely in their positions with reference to the end of their practice-curves (Wells: Am. Jr. Psych., 23:82-85). This objection appears to be removed if, upon the grounds of qualitative difference in work, capacities differing widely in initial status are declared to be not directly comparable, and if, upon grounds of individual variation in the form of practice-curves or of multiple types of practice-curves, the individual's position on the practice-curve cannot be determined and, consequently, no remedy is apparent.

'general effect' was said to decrease directly with decrease in similarity of matter and method between the two tests.[143]

More recently, the 'Common Factor' has been found to be made up of subjective factors, not altogether, but largely, independent of the matter and method of the tests (admirably shown by individual variation), and to be anything but simple, although the illustrations used in discussion are still apt to give it the appearance of a simplicity and definiteness which the authors do not really intend.[144]

If one set of processes consists of elements *a,b,c,d,e,* and another of *e,f,g,h,i,* training in the one is said to improve the other through the common factor *e;* the effect is greater in case the latter set should consist of *c,d,e,f,g.* Fracker[145] has suggested the term 'Transference' for this kind of influence, but he provides for another kind of 'general effect' which he calls 'Spread of Training,' which is found when the second set of processes consists of *f,g,h,i,j,* none of the elements of which is common with any of the first set but some of which are 'consciously' or 'subconsciously' connected with some of the latter in the mind of the reagent.[146] And Sleight[147] claims that to be effective the 'common factor' need not be recognized by the reagent as common; and that it may not be effective at all because it is so firmly bound up with its associates that it cannot be lifted out and used where its associates are not also common.

[143] *Vid.* Thorndike and Woodworth, 1901, *op. cit.*

[144] *Vid.* Fracker, 1908, *op. cit.* Sleight, 1911, *op. cit.*

[145] Fracker, *op. cit.* 85.

[146] The writer believes that Fracker has performed a real service in pointing out those distinctions and in offering apt technical terms for them; and he has adopted the terms in the preceding pages, but has thought best to characterize them in a different way, suggested by the two widely different classes of elements that contribute to improvement in training: The sudden rise of the curve in the beginning stages is due largely to 'adaptive' changes in which elements of former experience have been 'transferred' bodily to the new work; the later, more gradual, rise, broken by plateaus, is due to a more orderly development which was called "practice effect proper." The influence of this practice-effect, apart from transference, was termed "spread of training (see p. 230).

[147] Sleight, *op. cit.* pp. 440f.

To locate and define the 'common factor,' a thorough analysis of a set of processes into its elements is necessary; and this is exceedingly difficult because introspections, even when expertly made, are scarcely ever complete descriptions and reveal only the elements selected from the content of consciousness which enjoy a considerable degree of clearness. No doubt this incompleteness tends to a portrayal of the elements as discrete units connected in simple mechanical relations somewhat congruent with the old associational psychology. Admittedly incomplete analysis, however, yet shows, when it is at its best, that the elements found are not of the same order and are not simply related.

a. *Factors involved in one experiment*

The difficulty of defining the common factor and of stating the laws under which it operates, may be best apprehended, perhaps, by following a single experiment through its three or more parts in an effort to locate some of the elements of the processes which may serve as the 'Common Factor':

(1) The first period, between the 'ready' signal and the appearance of the stimulus, is characterized by a set of consciousness which includes certain predispositions or tendencies which affect the course of the processes to follow. It includes an emotional attitude toward the experiment and a corresponding 'will to succeed'; definite ideals of efficiency to be attained; ideas of method to be used. This 'anlage' comes to every experiment as an adaptation to a more or less novel situation, and is generalized therefore from past experience, is modified in recurring experiments on the basis of the resultant experiences from the foregoing; and engages at once the selective function of attention in the adaptation, and the function of control in carrying out the initial steps of the purpose, such as the readiness for a certain direction and distribution of the attention, and renewal of definite imagery which is to be used in ready recognition or reception of the material.

(2) The period of dealing with the stimulus may be either short or long. (a) If short, as in simple reaction, sensible dis-

crimination, or tachistoscopic work, quickness of adaptation or alertness of the attention, as well as degree of concentration, is a condition of good performance, since it affects directly sensitivity for the stimulus. The direction and distribution of the attention prepared for are carried out; part-processes are coördinated, external and internal distractions are inhibited, unessential imagery is reduced to a minimum. (b) If long, as in repeated reactions (card-sorting, typewriter-reaction, marking out *a's*), or in memorizing, there are in addition to the foregoing, sustained attention, more complicated part-processes, greater use of categories of classification, more development of method in process, more use of individual forms of imagery. In any case the process varies more with the form (in reaction, or memorizing) than with the material of the experiment.

(3) In tachistoscopic or memory work the period between the stimulus and recording may be used chiefly to make imagery definite for recording and may also serve for 'maturing' content into the field of clearness. In sensible discrimination it may serve for comparison of images. The control of the attention is therefore important, else the vague imagery will not be so directly entertained, and distraction will cause a loss of some of the clear imagery. Coördination of retaining and defining processes is demanded.

(4) In the period of recording, coördination of the retentive and reproductive processes call for economic distribution of the attention.

A single experiment thus contains many factors of a formal nature which cannot be treated as coördinate elements.[148]

b. *Practice-effect upon these factors*

Analyses of processes in training and tests in the preceding experiments show in what way these factors are changed through training:

(1) The attitude becomes optimal in tone, the 'will to suc-

[148] And consequently cannot be illustrated by a, b, c, d, e, f, etc., as though simply and mechanically related either with each other or with 'content' elements.

ceed' is firmer, the essential processes can be more definitely prepared for in the set of attention, strong expectation of particular content drops away.

(2) (a) Where the period of dealing with the stimulus is short, as in reaction and sensible discrimination, intensity and direction of attention comes under better control, resulting in greater sensitivity for the stimulus, greater preparedness for reaction, or higher discriminability, and closer coördination of sensation and movement or of discrimination and report. Adventitious imagery drops away. (b) Where the period is long and the processes are successive and complex, as in reaction with discrimination and choice (card-sorting, typewriter-reaction) there is first an elaboration of method involving analysis and classification of the stimuli and synthesis of like stimuli and similar relations into a scheme which mediates between stimulus and reaction. Improvement here consists in adaptability in forming an adequate scheme, and in an economic distribution of the attention to the various part-processes it involves. Then comes the dropping away of retarding factors, the stimulus becomes coördinated with its reaction, and improvement here consists in sustained attention and in a distribution of attention which equalizes readiness for all reactions; kinaesthetic accompaniments of recognition (as pronouncing, or movement of some part of the body) and of initiating the reaction, and those grosser bodily movements, tensions, and strains, accompanying effort, drop away.

In memorizing cards of exposed letters, figures, or symbols, methods of analyzing, classifying, and grouping, and of coördinating part-processes involving disparate imagery and different grades of clearness, grow up; systems of representative imagery (associations) develop; complexity of content increases from a two-fold to a four-fold system of imagery, and from a two-level to an eight-level grade of clearness.

Improvement in this part of the experiment involves factors which are common to all processes of learning, and also factors which are specific to the material or the form of the experiment. But the relative importance of these two classes of factors may

be illustrated from reaction with discrimination and choice. In no exercise, probably, are the special factors more important. The process of forming coördinations between specific stimuli and specific reactions is the end attained by the training. Yet those specific coördinations constitute the least part of the training effect; power of forming coördinations between other specific stimuli and other specific reactions has been so much increased that learning new systems is greatly facilitated.[149] Memorizing furnishes another illustration: Methods of apperceiving and representing the material are more permanent than the material learned, and have a wider application.[150]

(3) In the period of fixing the imagery and of 'maturing' vague imagery into impressions definite enough for cognition, improvement consists in a peculiarly delicate control of attention in respect to direction, to distribution, and to degree; and this experience once realized probably makes it possible to entertain any kind of imagery in the same way. (It resembles in nature the hearing out of an 'upper partial' from the complex clang of a vibrating string, in that stimulation directs the attention; but it is not so simple a process.) Improvement through training has the effect of increasing sensitivity to central excitations, of increasing both the liability and the fidelity of reproduction.

(4) Improvement in coördinating the retaining, reproductive, and recording processes effects an economic distribution of attention which results in a singular self-possession and poise, a satisfying feeling of fitness for the task. Economic distribution of the attention to such complex processes is a matter more of form than of content, for both stimuli and form of expression may changé yet that complicated formal process is to some extent available.[151]

This statement has necessarily been made in general terms and has emphasized the more formal elements which are fitted to fill the office of the 'Common Factor.' The more concrete, and

[149] *Vid.* Bair, (*op. cit.*) and Liddle (*op. cit.*).
[150] *Cf.* Fracker (*op. cit.* 91), and Gamble (*op. cit.* 97, 149).
[151] *Cf.* Fracker (*op. cit.* 95).

presumably more specific elements, dependent upon the particular work of the task, have been abundantly illustrated in the discussions of test and training results. The more formal elements appear at this juncture to need emphasis since they are so likely to be overlooked, especially when the analysis is expected to lead to simple elements mechanically related.

c. *'Spread of Training'*

When the more orderly changes in processes effected by practice in one task are carried over to another we have what the writer thinks is best described as a *'Spread of Training.'* This occurred more conspicuously in the Experiment on Marking out Words, the Experiment on Sensible Discrimination, and the Experiment on Reproduction. The 'Common Factor' appears to be *formal* and to be relatively detached from the data of presentation, and, in the last experiment, from method. No systems of imagery were carried over. The practice-effect consisted in stripping the essential process of unessential factors, in facility in developing automatic coördinations, in establishing habits of higher order, in dealing more effectively with vague imagery, etc. This kind of general effect seems to rest more directly upon *modes of mental processes* than upon the material of experience, and seems capable of description largely in terms of emotional and volitional attitudes and of the control of attention.

d. *'Transference'*

The term *'Transference'* seems particularly applicable to the carrying over, from one task to another, of the *material of experience.* It takes place typically in the 'adaptation' to a novel exercise, and in the application of physiological processes and systems of imagery in an exercise similar to the exercise in which they were developed.

These two kinds of general effect of special practice bear to each other a relation analogous to form and matter in logic, and, although inseparable, should be discriminated for the purpose of prohibiting the limit of search for the 'Common Factor' to the case of 'Transference' alone. Enumeration of the elements of

the material of experience will then not exhaust the processes in an exercise, to be considered for the purpose of locating the 'Common Factor.' In preceding pages when the causes of general effect of practice have been discussed, in the review of the results of experimentation conducted by others,[152] and by ourselves,[153] some elements properly falling under the head of 'Spread of Training' were always included in the consideration. If the reader should glance over the 'Summary' (pp. 31ff) of the evidence for relationship between mental processes, from the literature, he will note that the eighteen numbered cases all involve 'Spread of Training,' all but eight involve it almost exclusively, and only two involve a large share of 'Transference.'

e. *Both kinds of General Effect selected from former experience*

It has already been pointed out[154] that elements of former experience contribute to the work of a test. This is applicable to both kinds of general effect, as may be seen by inspecting the analyses of processes in the last two experiments.

To illustrate, with reference to *'Spread of Training,'* the reagent comes to the experiment with emotional factors, volitional attitudes, and modes of mental processes already established: His work in tachistoscopic tests and in learning 12-letter-rectangles is influenced by favorite letters, preference given to right or left position, distribution of attention, *etc.*, in discrimination tests, by concern for an equitable distribution of 'greater' and 'less' judgments and by other factors leading to constant errors;[155] he gives preference to imagery of one particular sense-mode, as is illustrated by his representative imagery in tests in discrimination, and in memorizing, although he may vary this mode upon occasion, for varying content or method;[156] he comes to tests in learning 12-letter-rectangles, and in memor-

[152] Pp. 19, 22f, 23f, 27.

[153] Pp. 36ff, 41ff, 46ff, 61ff, 173, 217ff.

[154] Pp. 173, 180f.

[155] *Cf.* F. Angell's Review of "Zur Analyze der Unterschiedsempfindlichkeit" von Martin u. Müller, in Am. Jr. Psych., 1900, 11: 266-7.

[156] *Cf.* Segal, J: Ueber den Reproductionstypus und das Reproduzieren von vorstellungen. Arch. f.d. ges. Psychol., 1908, 12: 124-236.

izing, with tendencies designed to facilitate a particular method of coördinating imagery of different modes, and of placing reliance mainly upon methods of rote learning or of classification and grouping, and to tests in compound reaction and in memorizing visual symbols with principles of classification; *etc.*

To illustrate with reference to '*Transference*,' the reagent applies elements of the material of former experience, especially in the forms of particular imagery and systems of imagery. To the former belong the conventional things by which visual symbols are cognized and named for memorizing; groups of letters from common phrases and names, cattle-brands, wheat-sack initials, names from Biblical and classical literature, *etc.* used in learning 12-letter-rectangles; the various representative visual and kinaesthetic imagery in discrimination of sound, as of flashing light, falling bodies, or raising the toes for louder sound; *etc.* To the latter belong the musical staff for memorizing 'note' forms, map directions for cognizing symbols with radii variously turned, series of steps for memorizing sound intensities, mathematical relations for grouping numerals, logical schemes for classification of stimuli in compound reaction; *etc.*

This application of the elements of former experience is familiar to every one who has considered at all critically the process of learning. But it should perhaps be pointed out that in the application the former elements are not merely picked up as stable units and mechanically inserted in a new process. The elements come with a certain mutation determined by the novelty of the situation, and their application involves a degree of invention. The elements of consciousness do not appear to behave in the manner of reflex-action, and it does not seem possible to get a purely 'specific' effect of practice when the practice is a conscious process. All elements may be the 'Common Factor'; all effects of conscious practice are to some extent 'general effects.'

f. *Provisional classification of Common Factors*

In view of the complexity of the situation it is hazardous to attempt a complete classification of the 'Common Factors,' yet the writer feels inclined to offer the following provisional list:

Common Factors

I. Objective.
   1. Likeness of material.
   2. Likeness of form.

II. Subjective.

A. FORM OF EXPERIENCE.

1. Aufgabe (interpretation of instructions).
2. Attitude (emotional, volitional).
3. Ideals (controlling concepts).
4. Purpose (definition of volitional attitude).
5. Intellectual processes.
   a. Elaboration of method.
   b. Short-circuiting of processes.
   c. Higher order of control.
   d. Elimination of accompaniments of
      (1) Discrimination,
      (2) Cognition,
      (3) Movement,
      (4) Reproduction.
   e. Growth in simplicity or complexity of imagery.
   f. Coördination of part-processes.
6. Control of attention.
   a. In degree,
   b. In direction,
   c. In distribution,
   d. In quickness of adaptation,
   e. In duration of concentration.

B. MATERIAL OF EXPERIENCE.

1. Simple imagery (Visual, auditory, kinaesthetic, tactual, *etc.*) .
   a. Direct.
   b. Associative.
      (1) In the same sense-mode.
      (2) In different sense-mode.
2. Compound imagery (Of the above).
   a. Direct.
   b. Associative.
3. Complex imagery. (Spatial, temporal, causal, histrionic).
   a. Direct.
   b. Associative.
4. Systems of Imagery (Representative schemes, mnemonic devices).

III. CONCLUSION[1]

1. Evidence from the literature of experimental psychology indicates a functional relationship between various mental processes. This relationship is sometimes positive, sometimes negative. Specially designed experiments show that 'specific' practice is never wholly 'general' in its effects; is often largely 'general,' and is probably always somewhat 'general.' Under the experimental conditions, the 'general' effect usually ranged, in amount, from one-fourth to three-fourths of the gain made in the specific practice (*vid.* Summary, pp. 31ff).[2]

2. Results of the repeated experiments of (a) Marking Out Words, and (b) Estimating Weights, support the evidence for 'general' effect of 'specific' practice, and indicate through introspective analysis, what change in the practice is responsible for the 'general' effect.

a. The training on Marking out Words, on printed pages, containing both letters *e* and *s*, increased efficiency by reducing the recognition of words as containing *e* and *s* to its essential process, through relieving it of unnecessary and retarding accompaniments, chiefly kinaesthetic, motor, and auditory. This factor in the training-effect was responsible for the marked increase in efficiency shown in the tests on marking out words containing other pairs of letters, on printed pages and on manuscript sheets. Some 'specific' effects of practice (such as word-reaction) which would not contribute to 'general' effect, or, if so, only in a negative form, were also found; but the principal factor of improvement in the practice was the main factor of improvement in the tests,—a general effect (34-39).

b. The training on Estimating Weights resulted in building

[1] The statements under this head will be found in more amplified form in the Conclusions of the various experiments, which may be located by reference to the Table of Contents.

[2] The page numbers in parenthesis refer to material upon which the statements are based, including conclusions to experiments.

up a definite idea of the field represented by the training weights (40-120 grams), or in deepening impressions of the weights at the upper and lower limits of this field; and these ideas of value improved the capacity for estimating weights differing in kind, both within the field of training and above it. Both reagents showed more improvement in tests on objects dissimilar to the training-weights, but within the field, than they made in training; and one reagent made his greatest gain in the test on objects above the field. These anomalous results, together with the introspective evidence of the complexity of the estimating process, suggest that simpler processes should be chosen for measuring and analyzing 'general' practice-effect (pp. 39-42).

3. The two experiments, (a) Sensible Discrimination, and (b) Reaction with Discrimination and Choice, designed to determine whether there is 'general' effect of 'special' practice when the processes involved are as simple as possible, and when the tests differ from the training (a) in sense-mode of reception of the stimuli, or (b) in the form of the stimuli and their motor-response, but when the tests and training involved the same kind of mental activity, contribute results indicative of the real complexity of the relatively simple processes, and of the 'general' nature of practice-effect.

a. Training in Sensible Discrimination of intensities of Sound resulted in improvement in efficiency through divesting the discriminating-process of its unessential and complicating factors consisting in irrelevant or fantastic imagery, indirect sets of attention, vascillating attention, expectation, *etc.*, all of which render judgment illusionable, and this improvement was transferred to the tests in sensible discrimination of shades of gray (pp. 42-50).

b. The training in sorting cards bearing distinctive colors into a cabinet with six compartments increased efficiency in Reaction with Discrimination and Choice, which was transferred to reaction to letters on a typewriter, (a) noticeably in regularity with two reagents for whom the latter had become automatic before the training in card-sorting was begun, and (b) markedly in speed

with two reagents for whom the latter was in course of practice. The practice-effect responsible for the improvement in the card-sorting and for the improvement transferred to the typewriter-reaction was (1) the habit of stripping the essential process of its adventitious accessories, consisting chiefly in (a) kinaesthetic and verbal elements accompanying and retarding the recognition of the stimulus, (b) mnemonic schemes which served the purpose of building up coördinations between stimulus and reaction, (c) false motions, and (d) bodily strain, and (2) such control of the attention (a) that the various possible reactions were about equally prepared for and (b) that the series of continuous reactions were not so frequently broken by balks due to distraction (pp. 50-64).

4. Disagreement in the results of investigations as to the extent of the general effect of special practice, in hypotheses proposed for the causes of the transference of practice-effect, and the frequency of cases of an anomalous character which defy any consistent hypothesis, are probably due to differences in technical procedure in experimentation, to differences in kind and length of training and in the relation of training to tests, and to differences in statistical treatment of results. They call for more qualitative investigation to the end of determining more precisely how training affects the processes engaged in the training, how training-effect affects the test-capacities, and how training-effect, both direct and 'general,' may be properly expressed in quantitative terms. A study of anomalous cases suggests the importance of determining (a) the extent of variability in processes, both with a single reagent and between different reagents who set themselves to the same objective task, (b) the causes of this variability, and (c) its effect upon the scores (pp. 64-69).

5. The Experiment on Attention, which provided a qualitative study of the kind, extent, and causes of variability in processes engaged by a single reagent in a single test and in a range of tests, and of variability between processes engaged by different reagents in identical tests, yielded results which show:

a. That it is the rule for the individual reagent to vary his processes while at work on a single test and often to change

radically, in the final test, the methods of work employed in the first.

b. That the causes of this variability, beyond general conditions of health, interest, *etc.*, and incidental occurrences, such as winking at the moment of the presentation of the stimuli, and accidents in manipulation of a key, *etc.*, were of a fairly specific nature varying in accordance with the nature of the work of the test, such as voluntary or undesigned shifts of the attention to various elements of the processes engaged, changes in the extent of the distribution of the attention over part-processes and their coördination, the constructing of more adequate methods, and the practice-effect of dropping out of the process unessential factors, in heightening sensitivity, discrimination, reproduction, habituation to distraction, and in building up habits of higher order.

c. That in almost every test individual reagents differ from each other, often greatly, in the way in which they performed the work of the test.

d. That they differ in the 'aufgabe,' or their understanding of the instructions for the test, in their general experience from which elements are selected, by way of adaptation, to begin work, in the order and degree of the changes in processes due to the variability in the single reagent's work noticed in (b) above (pp. 64-184, particularly 167-173).

6. The training results of this experiment brought into clear relief the fact that practice-effect itself involves changes in processes: At the beginning of training on Test 17, only letters that had been clearly seen were recorded; at the end, letters were correctly recorded that had not been "seen," but that 'matured' from the 'fringe' content of consciousness; the conquest of the 'fringe' content was a practice-effect that extended the area of distinct perception whilst increasing efficiency on its own account. At the beginning of training on Test 13, only letters the visual impression of which was converted into kinaesthetic-auditory (verbal) imagery were recorded; at the end, letters were recorded from four distinct kinds of imagery; at the beginning, the process was a simple 'rote' process; at the end, it was a complex process

involving coördination of many part-processes. The conception that repetition in the learning-process increases efficiency similarly to repetition of a skilled movement in fixing a habit is an absurdity against which the fact of the increasing keenness of consciousness accompanying the progress of the former ought to have been sufficient warning. Repetition in learning changes the process (pp. 173-176).

7. Altho the series of tests proved inadequate as a measure of attention, there was some quantitative indication of a practice-effect upon certain forms of attention (or attentive forms of consciousness) that were of general application: (1) The control of attention to seize the stimuli of the moment; (2) equitable distribution of the attenion over the various part-processes, leading to coördination of disparate imagery, of processes of retention and reproduction, or of imagery and movement; (3) sustained application, involving inhibition to external and internal distraction; (4) an intensity of application, effective in lowering thresholds of sensation and reproduction, and in fusing coördinations (pp. 178-180).

8. There was ample introspective evidence for general effect of special practice, both negative and positive. Not only were methods of work, forms of processes, and systems of imagery, transferred from one kind of work to another, but in the adaptation to the novel work of the tests elements of former experience were selected and applied, which when acquired must always have been 'specific' and as applied are always 'general' (pp. 180-181).

9. The Experiment on Reproduction supplemented the preceding experiment in illustrating the great variability in processes engaged in a single test, locating the variability in each successive 'moment' of the single test, and in offering new evidence, both quantitative and qualitative, for the positive and negative general effect of special practice, when the tests and training differed so greatly in both material and method as to exclude a 'transference' of the elements of experience (184-219).

10. The training on discrimination of sound did not result in improvement in efficiency with the training material. But, ac-

cording to introspective evidence, it effected changes in the processes employed. Quantitative analysis showed that the practice-effect of the evident exercise of retention and reproduction of auditory and other imagery 'spread' to the tachistoscopic test of Recognition or Choice of One of Two Letters, and to the test on the Complete Learning of series of visual symbols, both of which involved retention and reproduction of imagery (pp. 184-219). Retrogression in efficiency in the course of practice, and failure to apply methods developed in training to material slightly different, *etc.*, indicate a negative special effect of special practice, which should be taken into account when testing for general effect. The retrogressive effect shows itself in negative general effect in tests similar to the training, and is not inconsistent with positive general effect in tests less similar to the training (p. 219).

11. Data from the latter two experiments indicate the important bearing which variability in processes has upon the quantitative treatment of results (pp. 167-176, 181-184). Certain precautions need to be taken in order that the results of the test-training-test type of experiment may not be misleading (pp. 219-224). It would seem that purely quantitative results are worthless.

12. Introspective description of the processes involved in the successive 'moments' of a single experiment, and of practice-effect upon them, indicates such a complex relationship of the elements or part-processes that are fitted to perform the office of the 'Common Factor' that it seems doubtful if there are any purely 'specific' elements in the conscious process. The 'Common Factor' may be constituted of formal modes of consciousness (emotional and volitional attitudes, modes and habits of consciousness, control of attention) in which case it effects 'Spread of Training'; or it may be constituted of the material of consciousness (imagery, systems of imagery, direct and representative) in which case it effects 'Transference' of the elements of experience. Search for the common factor should not be so conducted as to locate only the latter form; experimental evidence indicates that the former is more largely

responsible for the general effect of special practice. In both forms it is selected[3] from former experience and applied with some degree of invention to a more or less novel situation. It would seem that 'adaptability' consists in this 'general' use of the forms and elements of experience which had their origin in 'specific' reactions to specific stimuli,' and that the desideratum of the 'learning process' consists in extending the 'general' applications as widely as possible.[4] There is evidence that all modes and elements of experience may be the 'Common Factor'; that all effects of conscious practice are to some extent 'general' effects (pp. 224-233).

13. Discussion throughout the text makes it clear that much further work is needed in this field. With improved method a complete survey of functional relationship between the mental processes should be made. Many outstanding questions await attack: Conditions favoring and limiting 'general' effect, the scope and causes of negative influence, the duration of direct, and of the various 'general' applications of, training-effect, and its dependence upon length and rigor of training and upon kind of work; relative dependence of individual variation in processes upon nature and nurture; dependence of efficiency upon training in a 'best way' of performing a mental task, *etc.*[5]

[3] This selection and application is not necessarily purposeful or even evident to introspection. The value of introspection, as has been pointed out in the text (p. 181), does not rest upon its assertion or denial of relationship between processes, although its testimony concerning this may often be true, but upon a sufficiently complete and accurate analysis of processes that their relationship may be evident. It is particularly competent to show in this way 'Transference' of the elements of experience; 'Spread of Training,' however, is likely to escape detection unless analyses are especially complete, for it is sometimes extremely subtle and evident only through quantitative analysis (as in the Experiment on Reproduction).

[4] Colvin (Some facts in partial justification of the so-called Dogma of Formal Discipline. Univ. Ill. Bull. 1910. 7: No. 26, p. 31; also, The Learning Process. 1911. Pp. 242ff) makes a plea for the application of this principle in school work, and gives "rules for securing transfer," or for securing a "general" training.

[5] The circuitous process of testing and abandoning various methods of work which often retards reagents in course of practice, and the arrest of an occa-

After investigation has profited by adult introspective analysis and it has been carried out with adolescents, trained in introspection, and has been quantitatively checked by results from children, we may perhaps by reason of our intimate knowledge of the functional relationship of mental processes, the integration of experience, the formal learning-process, be able to determine whether the limited time given to formal education should be spent primarily for discipline or for knowledge, whether information and aims belonging to adult vocations are as vital in the educative processes of children as such information and aims as are incidental to the successful functioning of experience through graded steps in a formal training.

14. Meanwhile, experimental research in the psychological laboratory has established certain functional relationships between mental processes more or less simple, and has singled out factors responsible for the transference of improvement from one exercise to another. Its contribution to the general question of formal discipline is important, in that it shows the general effect of special practice; but it is limited in its scope to fairly simple processes, to periods of short training, and, for introspections, to reagents upon whom training does not produce great practice-effect. Were the processes as complex and various as those engaged in the study of Greek, Mathematics, or Science; were the training to extend over four school-years instead of over ten weeks under limiting laboratory conditions; and were the subjects in the plastic period of the 'teens,' it is conceivable that the extent to which the training is general would be found to be greatly in excess of the laboratory figures.

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sional reagent upon a low plateau by reason of a peculiarly inept method of work, suggest that training in 'good form' might be the better part of practice, especially in the early stages, but also in the later stages which involve transitions to new coördinations of part-processes. This phase of practice is considered important in athletics, and in the trades involving skilled movements; and Swift (Studies in the psychology and physiology of learning. Am. Jr. Psych., 1903, 14: 224) suggests its application to the early stages of learning skill, while Bryan and Harter (Studies on the telegraphic language: The acquisition of a hierarchy of habits. Psych. Rev., 1899, 6: 375), by pointing out the end-processes of training, suggest its place in the acquisition of skill in such types of learning as involve hierarchies of habits.

15. The contribution of Experimental Psychology to the educational theory of training is timely, since intensity of work and drill[6] is coming into vogue again. It is found that great effort and rigorous drill are necessary to pass through 'plateaus of growth' or, as Bagley[7] calls them, "sloughs of despond." There seems to be a disposition to find the conditions of training that will "unlock reservoirs of higher power,"[8] and those who find satisfaction in physiological explanations are turning to the theory of the 'synapse'[9] and the "All or None"[10] principle. This increase of power is deemed necessary for the acquisition of such mental habits and such knowledge as, under the conditions of our civilization, constitute a reasonable preparation for complete living.

[6] Beckwith: Drill, a chapter in pedagogy. 1905.
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[7] Bagley: Craftsmanship in teaching. Macm. 1911.

[8] James: Energies of men. Science, 1907. 25: 321; also Am. Mag. Nov. 1907.

[9] Sherrington: Integrative action of the nervous system. Scribner's. 1906.

[10] Stiles: "All or None" principle and its implications. Am. Phys. Ed. Rev. 1910. 15: 1.

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APPENDIX

APPENDIX A

TABLE I.

Improvement as Shown by Tests on Other Functions Before and After 11 Days' Training on *e-s*

(Text p. 35)

	Reagent Gs						Reagent Cr					
	Speed in Sec.		Accuracy				Speed in Sec.		Accuracy			
	Before Training	After Training	No. of Words Marked B.	A.	Omitted B.	A.	Before Training	After Training	No. of Words Marked B.	A.	Omitted B.	A.
e—s	199.5	85.6	35	45	12	2	133.3	91.8	46	47	5	0
i—t	390	108.6	56	40	3	9	136.9	120.2	37	42	4	8
s—p	111.5	95	9	15	1	0	89.4	66.2	15	10	2	1
c—a	198	124.8	22	19	0	6	116.6	85.6	25	27	0	2
e—r	223	134	53	53	9	7	166.5	135.6	52	58	8	0
Totals	922.5	462.4	140	127	13	22	509.4	407.6	129	137	14	11
a—n	248	177.8	37	39	9	10	172.8	142.2	31	35	15	14
l—o	178	133.5	15	6	1	4	135.8	88.6	16	9	0	1
e—r	214	138	61	40	7	6	212.8	134	62	42	7	4
Totals	640	449.3	113	85	17	20	521.4	364.8	109	86	22	19
Nouns	160	137.8	79	77	2	2	196.7	184.6	66	80	4	11
e—s	175	99.2	38	49	2	0	137.6	93	42	46	2	3
Functions on Same Mt	922.5	462.4	140	127	13	22	509.4	407.6	129	137	14	11
Diff."	640	449.3	113	85	17	20	521.4	364.8	109	86	22	19
Total	1562.5	911.7	253	212	30	42	1030.8	772.4	238	223	36	30

TABLE II

Improvement Shown by Percentages of Tests after Training to Tests before Training (Text p. 35)

	Reagent Gs.		Reagent Cr	
	Speed % of After-Test	Accuracy % Words Mkd	Speed % of After Test	Accuracy % Words Mkd
e-s[1]	.43	1.28	.69	1.11
i-t[2]	.28	.86	.88	.93
s-p	.85	1.11	.74	1.03
c-a	.63	.76	.73	.93
e-r	.60	1.03	.81	1.15
a-n[3]	.71	.99	.82	1.06
l-o	.75	.64	.65	.90
e-r	.64	.97	.63	1.02
Nouns	.86	1.00	.94	.93
e-s	.57	1.05	.68	.98
Functions on				
Same Mat'l	.50	.93	.80	1.03
Diff. Mat'l	.70	.93	.70	.98
Of Total	.58	.93	.76	1.01

[1] The Trained Function.
[2] Employed on Same Material as Training Mat'l, . . . Printed Columns.
[3] Employed on Different Material, . . . Manuscript.

TABLE III

Quantitative Results (Text, p. 39)

Reagent Gs.

	Total Dev. What % of Whole Weight Lifted		Avg. Dev. in Grams		% of Gain
	Before	After	Before	After	
Tests in Training Series (40-120 grams) (Avg. 80)	12.1%	8.2%	9.7	7.2	25.8%
Objects inside of field (49-113 grams) (Avg. 67.5)	29.7%	22.1%	20.1	14.9	28.4%
Objects outside of field (146-1870) (Avg. 552.7 g.)	52.8%	29.8%	291.9	165.6	43.3%

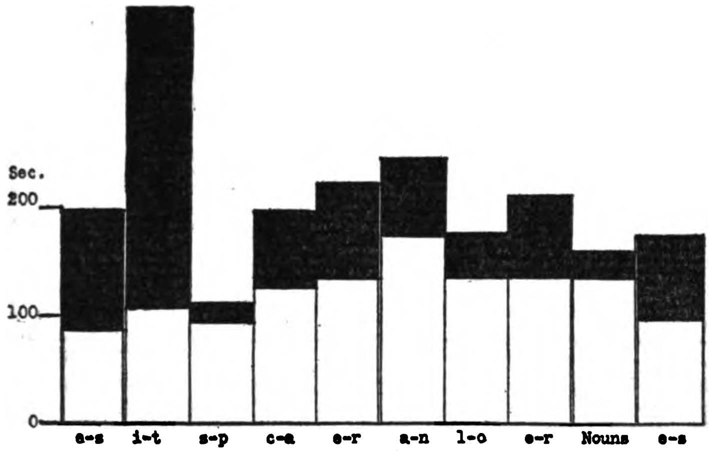


PLATE I. Reagent Gs. Efficiencies (in speed) in other Functions before and after Training on the e-s Function. The filled portion shows amount of improvement. (From Table I.)

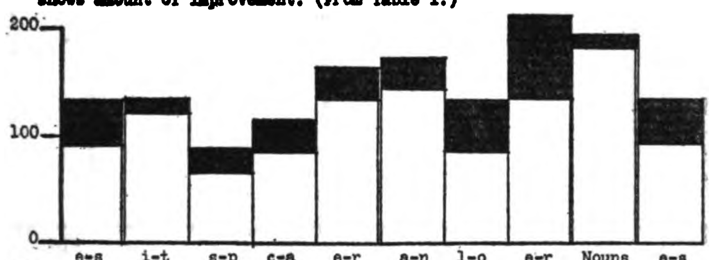


PLATE II. Reagent Cr.

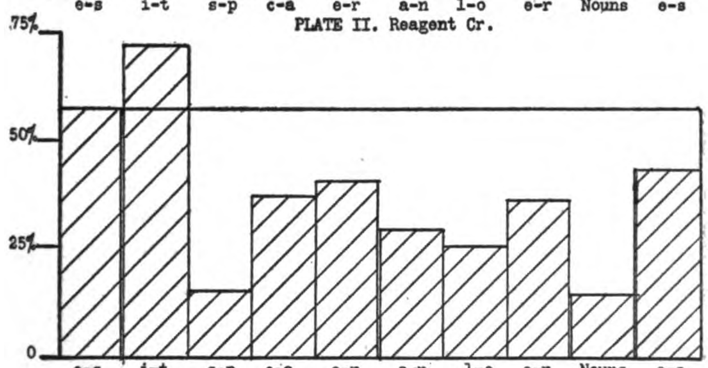


PLATE III. Reagent Gs. Gain shown in per cent. Checked portion shows amount of improvement transferred.

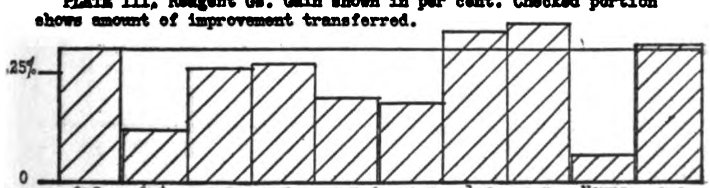


PLATE IV. Reagent Cr.

(See Text, p. 35)

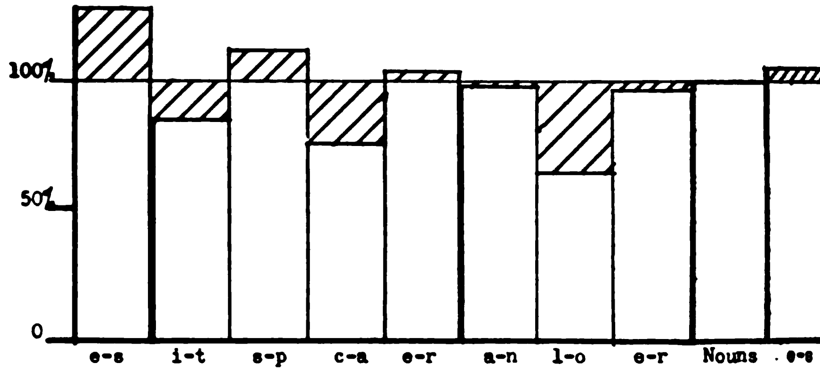


PLATE V. Gs, reagent. Accuracy in percent of initial capacity. Checked portion shows amount of change. (From Table II.)

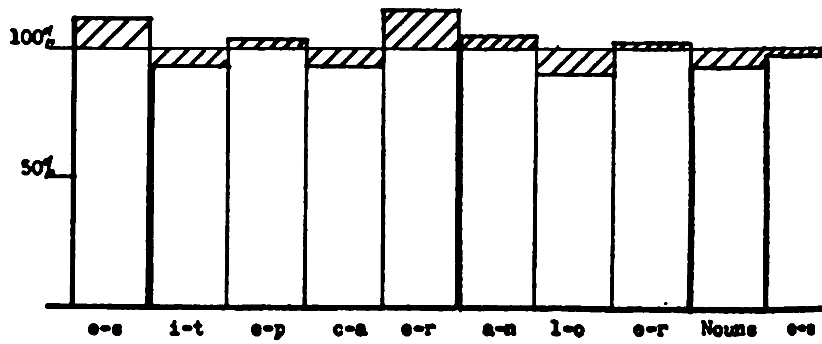


PLATE VI. Reagent Cr.

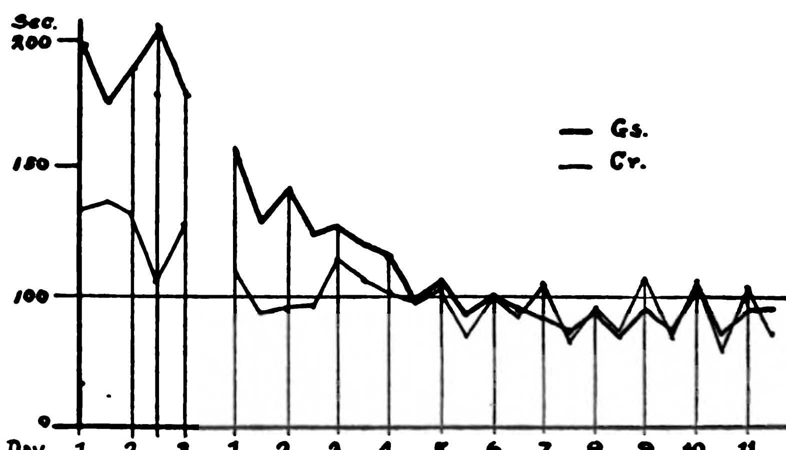


PLATE VII. Practice-Curve from tests taken at beginning and end of each day's training of the e-s Function.

(See Text, pp. 35, 38)

TABLE IV

(Text, p. 39)

Reagent Cr.

	Total Dev. What % of Whole Weight Hefted		Avg. Dev. in Grams		% of Gain
	Before	After	Before	After	
Tests in Training Series (40-120 grams) (Avg. 80 g.)	11.2%	09.0%	8.7	7.2	20%
Objects inside of field (49-113 grams) (Avg. 67.5 g.)	26.1%	18.5%	17.6	12.5	29.2%
Objects outside of field (146-1870 g.) (Avg. 552.7 g.)	15.3%	52.7%	84.8	291.6	-243.9%

TABLE V

(Text, p. 39)

Reagent Gs.

Suggestion Blocks

	Wt. of Blocks	Before Training			After Training		
		1st	2d	Total	99th	100th	Total
	40	0	+15	15	+5	+5	10
	45	+15	0	15	0	+10	10
	50	—10	—10	20	—10	+5	15
	55	+15	+10	25	—5	+5	10
	60	+15	0	15	—5	—10	15
	65	—15	+15	30	0	+5	5
	70	0	—5	5	0	—5	5
	75	0	0	0	+5	0	5
	80	+5	+10	15	0	—10	10
	85	—20	—20	40	—15	—10	25
	90	+15	—5	20	+5	+15	20
	95	+15	—20	35	0	+20	20
	100	+35	—15	50	0	+10	10
	105	0	—5	5	0	—10	10
	110	+20	—5	25	+10	—20	30
	115	0	0	0	—5	—15	20
	120	+5	—10	15	—10	—15	25
Totals		185	145	330	75	170	245
Average				165			122.5 25.8% Gain

TABLE VI

(Text, p. 39)

Reagent Cr.

Wt. of Blocks	Before Training 1st	2d	Total	After Training 99th	100th	Total
40	0	0	0	0	0	0
45	—5	0	5	—5	—5	10
50	0	—5	5	0	+15	15
55	+5	+10	15	+5	—5	10
60	—10	—15	25	0	+10	10
65	+15	+10	25	+10	+10	20
70	+5	—15	20	0	+5	5
75	+20	—25	45	—10	+5	15
80	—30	0	30	—20	—5	25
85	0	—10	10	—15	+20	35
90	+20	+5	25	—10	+15	25
95	+20	0	20	+15	—5	20
100	0	+10	10	—10	—10	20
105	+10	+5	15	—5	—5	10
110	—20	—10	30	—5	+5	10
115	0	+5	5	—5	—5	10
120	—20	—5	25	0	—5	5
Totals 175	175	130	305	115	130	245
Average			152.5			122.5 20% Gain

TABLE VII

(Text, p. 39)
Deviations on Objects

Gs.

Inside Field	Wt.	Before Training 1st	2d	Total	After Training 1st	2d	Total
1. Big Wt.	81	—31	—6	37	—26	—16	42
2. Bar soap	113	—13	+2	15	+13	—28	61
3. Eraser	67	—22	—17	39	—2	—7	9
4. Pocket Bk.	81	—1	—21	22	—1	—1	2
5. "Outlook"	105	—60	—60	120	—30	—50	80
6. Keys	52	—2	—7	9	—7	+3	10
7. $3 silver	80	+10	+20	30	—5	0	5
8. Small Bottle	63	—18	—13	31	—18	—8	26
9. Elec. bulb	49	+6	+46	52	+21	+26	47
10. Elec. switch	84	+21	+26	47	+6	+11	17
Totals	675	184	218	402	149	150	299
Average				201			149 28.4 Gain

TABLE VIII
(Text, p. 39)

Outside Field							
11. Big Bottle	317	—97	—127	224	—127	+8	135
12. "Outwest"	280	—105	—100	205	—80	—30	110
13. Mucilage	330	—143	—133	276	+67	—33	100
14. Münsterberg	714	—479	—364	843	—114	—214	328
15. Mem. App. Wt.	941	—641	—441	1082	+159	+359	518
16. Ps Molding	146	—16	—16	32	—16	—6	22
17. Hammer	310	—165	—120	285	—135	+65	200
18. Tin Box	462	—257	—162	419	—62	+38	100
19. Key Mem.	154	—24	—9	33	+6	—4	10
20. Psy. Rev.	1870	—1370	—1070	2440	—920	—870	1790
Totals	5527	3297	2542	5839	1686	1627	3313
Average				2919.5			1656.5
							43.3% Gain

TABLE IX
(Text, p. 39)
Deviations on Objects

Cr.

Inside Field	Wt.	Before Training 1st	2d	Total	After Training 1st	2d	Total
1. Big Wt.	81	—1	—6	7	—11	—11	22
2. Bar Soap	113	—13	—38	51	—3	+2	5
3. Eraser	67	—17	—22	39	—7	—7	14
4. Pocket Bk.	81	+19	+29	48	—21	+29	50
5. "Outlook"	105	—5	—5	10	—15	—5	20
6. Keys	52	—2	—7	9	+13	+8	21
7. $3 Silver	80	+20	+40	60	+15	+20	35
8. Small Bot.	63	—7	+27	34	—18	—18	36
9. Elec. Bulb	49	—4	+41	45	+1	—4	5
10. Elec. Switch	84	—24	+26	50	+26	+16	42
Totals	675	112	241	353	130	120	250
Average				176.5			125
							29.2% Gain

TABLE X
(Text, p. 39)

Outside Field							
11. Big Bottle	317	—117	—117	234	—77	—77	154
12. "Out West"	280	—5	+120	125	+70	+20	90
13. Mucilege	333	+67	+17	84	+667	+567	1234
14. Münsterberg	714	—214	—114	328	+286	+86	372
15. Mem. App. Wt.	941	+59	+59	118	+59	+59	118
16. Pc Molding	146	+104	+104	208	—21	—16	37
17. Hammer	310	—10	+90	100	+40	+90	130
18. Tin Box	462	—87	—62	149	+238	—162	400
19. Key Mem.	154	+4	+96	100	—14	—24	38
20. Psy. Rev.	1870	+130	—120	250	+1130	+2130	3260
Totals	5527	797	899	1696	2602	3231	5833
Average				848			2916.5
							243.9% Loss

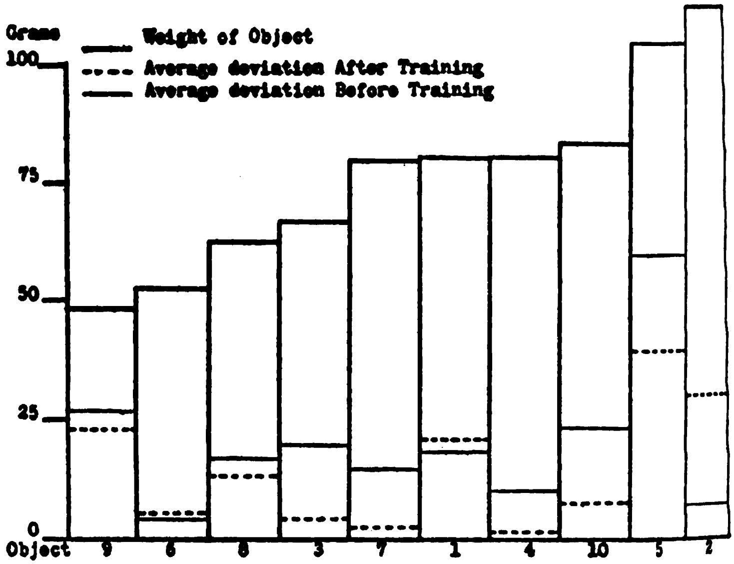


PLATE VIII. Reagent Ge. Weights of Objects Inside the Field, and average deviations of judgments. (From Table VII.)

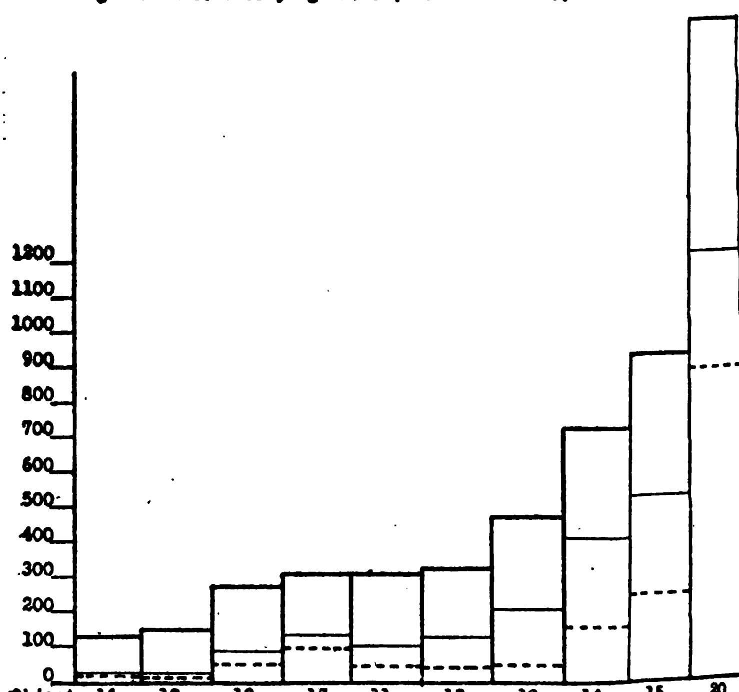


PLATE IX. Reagent Ge. Objects Outside of Field.
(See Text, p. 40)

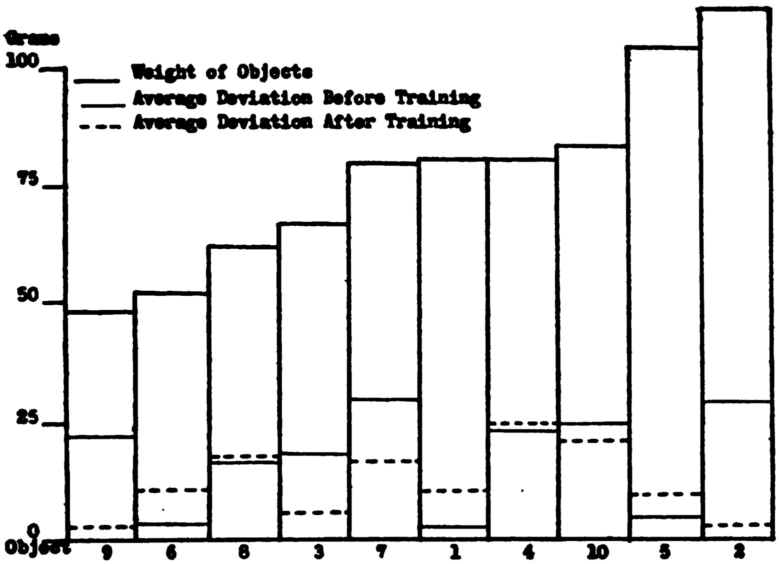


PLATE X. Reagent Gr. Weights of Objects inside the Field, and average deviations of judgments. (From Table IX.)

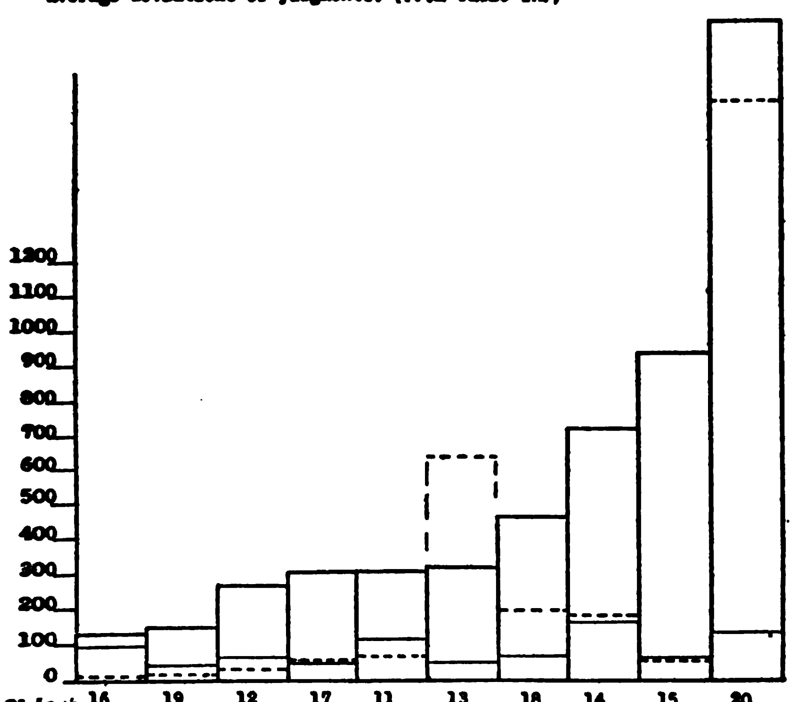


PLATE XI. Reagent Gr. Objects Outside of Field.
(See Text, p. 40)

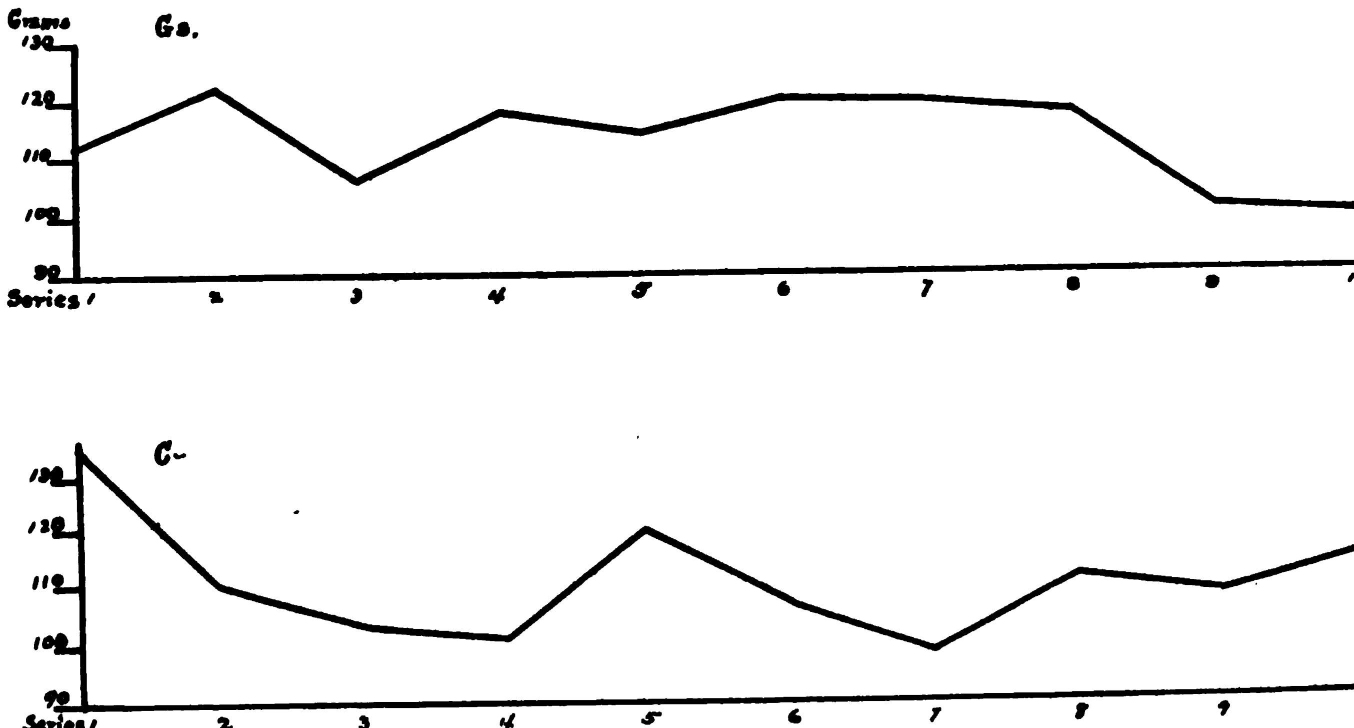


PLATE XII. Practice Curves. Estimating Weights Avg. Deviations for every successive 10 Series.
(170 Judgments in each plot)
(See Text, p. 40)

TABLE XI

Regular Reagents (Text, p. 44)
Brightness-Discrimination. Before Training
(Judgments on 90 variables)

Degrees of White	Aw. R	Aw. W	Aw. U	Aw. %R	Na. R	Na. W	Na. U	Na. %R	Ya. R	Ya. W	Ya. U	Ya. %R
160°	12	0	3	.80	11	1	3	.73	8	2	5	.54
165°	10	3	2	.67	10	0	5	.67	10	3	2	.67
170°	10	1	4	.67	4	2	9	.27	7	4	4	.47
175°	5	8	2	.33	3	2	10	.20	4	4	7	.27
180°												
185°	11	2	2	.73	8	1	6	.54	7	6	2	.47
190°	12	0	3	.80	10	0	5	.67	11	2	2	.73
Totals	60	14	16		46	6	38		47	21	22	
%R	66.7				51.1				52.2			
%U	17.8				42.2				24.4			

(21 Days' Training on Sound during an interval of 64 days)

TABLE XII

(Text, p. 44)
Brightness-Discrimination. After Training
(Judgments on 90 variables)

	Aw. R	Aw. W	Aw. U	Aw. %R	Na. R	Na. W	Na. U	Na. %R	Ya. R	Ya. W	Ya. U	Ya. %R
160°	15	0	0	1.00	14	1	0	.93	12	0	3	.80
165°	13	1	1	.87	8	4	3	.54	5	2	8	.33
170°	10	2	3	.67	7	4	4	.47	4	5	6	.27
175°	10	2	3	.67	4	7	4	.27	1	6	8	.07
180°												
185°	5	6	4	.33	7	1	7	.47	12	2	1	.80
190°	11	2	2	.73	12	2	1	.80	13	0	2	.87
Totals	64	13	13		52	19	19		47	15	28	
%R	71.1				57.8				52.2			
%U	14.4				21.1				31.1			

TABLE XIII

Regular Reagent Cr. (Text, p. 44)
Brightness-Discrimination

Degrees of White	Before Training (Judgments on 76 Variables) R	W	U	% R	After Training (Judgments on 80 Variables) R	W	U	% R
110°	8	0	2	.80	10	0	0	1.00
120°	6	1	2	.67	10	0	0	1.00
130°	5	3	2	.50	8	1	1	.80
135°	6	0	4	.60	4	2	4	.40
140°								
145°	2	2	6	.20	7	2	1	.70
150°	4	0	5	.44	9	1	0	.90
160°	6	0	3	.67	10	0	0	1.00
170°	7	0	2	.78	10	0	0	1.00
Totals	44	6	26		68	16	6	
% R		57.5				85.0		
% U		33.7				7.5		

TABLE XIV

(Text, p. 43)
Sound-Discrimination. Beginning Training
(Judgments on 60 Variables)

Intensity	Aw. R	W	U	% R	Na. R	W	U	% R	Ya. R	W	U	% R	Cr. R	W	U	% R
23.57	3	5	2	.30	5	3	2	.50	3	6	1	.30	4	3	3	.40
25.06	2	5	3	.20	3	3	4	.30	1	5	4	.10	5	4	1	.50
26.48	1	5	4	.10	5	0	5	.50	5	3	2	.50	6	0	4	.60
27.83																
29.12	6	1	3	.60	1	3	6	.10	4	1	5	.40	4	3	3	.40
30.35	5	2	3	.50	3	2	5	.30	6	1	3	.60	4	3	3	.40
32.68	5	2	3	.50	5	4	1	.50	7	2	1	.70	4	4	2	.40
Totals	22	20	18		22	15	23		26	18	16		27	17	16	
% R			36.7			36.7				43.3				45.0		
% U			30.0			38.3				26.7				26.7		

TABLE XV

(Text, p. 43)
Sound-Discrimination Ending Training
(Judgments on 60 Variables)

Intensity	Aw.				Na.				Ya.				Cr.			
	R	W	U	%R	R	W	U	%R	R	W	U	%R	R	W	U	%R
23.57	6	4	0	.60	5	2	3	.50	5	4	1	.50	6	4	0	.60
25.06	3	5	2	.30	4	2	4	.40	3	5	2	.30	6	4	0	.60
26.48	2	3	5	.20	4	3	3	.40	3	2	5	.30	6	2	2	.60
27.83																
29.12	8	2	0	.80	5	2	3	.50	5	0	5	.50	6	2	2	.60
30.35	6	2	2	.60	2	5	3	.20	4	2	4	.40	4	4	2	.40
32.68	6	4	0	.60	5	5	0	.50	4	4	2	.40	6	2	2	.60
Totals	31	20	9		25	19	16		24	16	20		34	18	8	
%R		51.7				41.7				40.0				56.7		
%U		15.0				26.7				33.3				13.3		

TABLE XVI

Control Reagents. (Text, p. 44)
Brightness-Discrimination. Before Interval
(Judgments on 60 Variables)

Degrees of White	Rl.				An.				Wr.			
	R	W	U	%R	R	W	U	%R	R	W	U	%R
160°	8	0	2	.80	4	2	4	.40	8	1	1	.80
165°	7	1	2	.70	5	3	2	.50	7	3	0	.70
170°	5	4	1	.50	4	2	4	.40	7	2	1	.70
175°	4	2	4	.40	4	3	3	.40	7	3	0	.70
180°												
185°	7	2	1	.70	6	2	2	.60	10	0	0	1.00
190°	10	0	0	1.00	8	1	1	.80	7	3	0	.70
Totals	41	9	10		31	13	16		46	12	2	
%R			68.3			51.7			76.7			
%U			16.7			26.7			3.3			

(46 Days' Interval Without Training)

TABLE XVII

Brightness-Discrimination. After Interval
(Judgment on 60 Variables)

Degrees of White	Rl.				An.				Wr.			
	R	W	U	%R	R	W	U	%R	R	W	U	%R
160°	9	0	1	.90	4	3	3	.40	9	1	0	.90
165°	8	1	1	.80	3	4	3	.30	10	0	0	1.00
170°	3	1	6	.30	4	2	4	.40	5	2	3	.50
175°	4	4	2	.40	4	5	1	.40	4	3	3	.40
180°												
185°	5	2	3	.50	7	0	3	.70	6	4	0	.60
190°	9	1	0	.90	8	1	1	.80	9	0	1	.90
Totals	38	9	13		30	15	15		43	10	7	
%R			63.3			50.0			71.7			
%U			21.7			25.0			11.7			

TABLE XVIII

(Text, p. 44)

Comparison of Data (Absolute Amounts)

Regular Reagents

A. Right Judgments

Tests	Aw.	Na.	Ya.	Cr.	Total
No. R Before	60	46	47	46	199
No. R After	64	52	47	68	231
Difference	+4	+6	0	+22	+32
Training in Sound					
No. R at Beginning	22	22	26	27	97
No. R at End	31	25	24	34	114
Difference	+9	+3	—2	+7	+17

B. Undecided Judgments

Tests	Aw.	Na.	Ya.	Cr.	Total
No. U Before	16	38	22	27	103
No. U After	13	19	28	6	66
Difference	—3	—19	+6	—21	—37
Training in Sound					
No. U at Beginning	18	23	16	16	73
No. U at End	9	16	20	8	53
Difference	—9	—7	+4	—8	—20

Control Reagents

C. R and U Judgments

Tests	Rl.	An.	Wr.	Total
Before and After Interval Without Training				
No. R Before	41	31	46	118
No. R After	38	30	43	111
Difference	—3	—1	—3	—7
No. U Before	10	16	2	28
No. U After	13	15	7	35
Difference	+3	—1	+5	+7

TABLE XIX

(Text, p. 44)

Comparison of Data (Relative)

(All per cents are reckoned upon the whole number of judgments represented in table)

Regular Reagents

A. Right Judgments

	Aw.	Na.	Ya.	Cr.	Total
Tests					
Per cent R Before	66.7	51.1	52.2	57.5	56.9
Per cent R After	71.1	57.8	52.2	85.0	66.0
Difference	+4.4	+6.7	0	+27.5	+9.1
Training in Sound					
Per cent R Beginning	36.7	36.7	43.3	45.0	40.4
Per cent R End	51.7	41.7	40.0	56.7	47.5
Differences	+15	+5	—3.3	+11.7	+7.1

B. Undecided Judgments

	Aw.	Na.	Ya.	Cr.	Total
Tests					
Per cent U Before	17.8	42.2	24.4	33.7	29.4
Per cent U After	14.4	21.1	31.1	7.5	19
Difference	—3.4	—21.1	+6.7	—26.2	—10.4
Training in Sound					
Per cent U Beginning	30	38.3	26.7	26.7	30.4
Per cent U at End	15	26.7	33.3	13.3	22
Difference	—15	—11.6	+6.6	—13.4	—8.4

Control Reagents

C. R and U Judgments

	Rl.	An.	Wr.	Total
Tests				
Before and After Interval Without Training				
Per cent R Before	68.3	51.7	76.7	65.5
Per cent R After	63.3	50	71.7	61.7
Difference	—5	—1.7	—5	—3.8
Per cent U Before	16.7	26.7	3.3	15.5
Per cent U After	21.7	25	11.7	19.4
Difference	+5	—1.7	+8.4	+3.9

TABLE XX

(Text, p. 91)

Orders for Cards

123621453463154256413243526516526153423 14

Continue Orders 1 & 4—612451364
Continue Orders 2 & 5—652361346
Continue Orders 3 & 6—652451362

Changes of Equivalence

	R.	Y.	G.	B.	Br.	Bl.
Order 1	1	2	3	4	5	6
Order 2	6	1	2	3	4	5
Order 3	5	6	1	2	3	4
Order 4	4	5	6	1	2	3
Order 5	3	4	5	6	1	2
Order 6	2	3	4	5	6	1

Colors:
*R*ed
*Y*ellow
*G*reen
*B*lue
*Br*own
*Bl*ack

By reversing the above 6 Orders the 12 Orders were made up.

TABLE XXI
(Text, pp. 53, 54, 56, 57)
Reactions on Typewriter (per 100)

A. *Before Training*

Cl. Sec.	Cl. Errors	Al. Sec.	Al. Errors	Cr. Sec.	Cr. Errors	Bs. Sec.	Bs. Errors
71	2	94	0	73	3	108.5	8
71	0	104	4.5	74	4	105.4	2
73	1	102	5	71.6	1	99.3	3
79	1	85	1	83	4	99.7	7
81	1.5	81	5	75	3.5	96.4	6
79	0.5	86	2	72.5	3	87.7	5
72	0	78	1	71.2	4.5	79.4	4
75	2	82	5	71	4.5	88.2	1
71	0	80	1	69.8	4.5	83.2	3
71	1	79	6	71	4	94.7	4
73	3	76	3	71.5	1	89.7	0
66	1	75.6	8	73.2	4	93.2	5
66.8	2.6	75.4	5.5	68.2	4	82.5	4
68.4	0	75.8	7	69.5	3.5	80.8	3
69.4	0	70.4	5	69	2	71.8	1
68	0	70.8	6	67.4	0	101.1	4.5
65.8	2	70.4	7	67.4	6	84.5	4
73.1	0	82.2	4	69.4	3	85.5	6
70.4	0	81.2	5	71.3	5	84.1	4
69	0.5	81.7	4.5	67.8	6	79.6	3
64.8	1	79.1	4.5	68.4	6	81	2
70.4	2.5	77.9	7.5	66.8	3	78.6	5
66.1	1.5	73.8	3	68.1	2	74.3	4
65.7	0.5	69.5	7	67.1	3	85.5	11
59.4	0	74.6	6	66.4	4	81.6	7
64.8	2.5	73.8	10	68.1	2	74.5	2
63.8	0.6	74.7	8	65.3	1	75.8	3
63.5	1	73.1	8			80.9	6
62.4	0	70.5	2.5			82.6	7
						77.1	5
						76.3	3

B. *After Training*

Cl. Sec.	Cl. Errors	Al. Sec.	Al. Errors	Cr. Sec.	Cr. Errors	Bs. Sec.	Bs. Errors
64.3	0	67.9	9	65.2	3	69.6	10
64	1	64.2	6.5	64.3	5	68.3	8
61	0.5	62.6	5.5	69.2	6	72.8	8
63.5	1.5	65.6	11	68.2	5	69.4	8
62.9	1.5	64.3	10	66.3	5	72.7	5
63	2.5	66.3	6	65.2	4.5	71.6	8
61.2	1	63.1	12	60.8	2	68.8	3.5
60.9	1.5	61.8	11	61.2	5.5	69.2	2
62.3	1	62.1	15	61.5	7	71.8	5
61	1	66.5	11	63	3	65.7	0.5
61.6	1.5	61.5	8.5	64.2	6	69.3	7
60.9	0	62.3	10.5	62	5	69	2
62.6	2	63.2	17	62.2	4	66.4	8
57.9	0	60.5	11.5	58.8	0	65.5	3
61.9	1.5	60.8	13.5	62.5	5	59.2	3
60.6	1.5	58.9	10	61	7	69.5	11
60.5	1	60.9	15.5	63.5	8	70.7	10
59.2	0.5	61.6	13	61.9	9.5		

TABLE XXII

(Text, pp. 53, 55, 56)
Reactions on Typewriter (Avg. per 100 per Day)

A. *Before Training*

Cl.		Al.		Cr.		Bs.	
Sec.	Errors	Sec.	Errors	Sec.	Errors	Sec.	Errors
71	2	94	0	73	3	99.5	5
76	0.9	93	4	76.0	3	87.3	3
73.5	1.1	80.0	3	71.2	3.5	84.0	4.5
67.4	1	73.1	6.3	69.1	3	80.1	5.3
69	1.0	79.3	4.5	69.1	5	77.9	4.3
63.3	0.8	72.7	7	67	4		

B. *After Training*

Cl.		Al.		Cr.		Bs.	
Sec.	Errors	Sec.	Errors	Sec.	Errors	Sec.	Errors
63.3	1	65.2	8	66.4	4.5	70.7	8
61.3	1	62.9	11	62.1	4.5	69	3.3
60.4	1	61.0	13	61.7	5.4	66.3	6

TABLE XXIII

(Text, pp. 53, 56, 57)
Reactions on Typewriter (per 100) (Control Reagents)

Before Interval

Mn.		Ge.		Gs.	
91.1	2	147.3	7	107.1	0
95.7	3.6	125.7	4	79.1	0
91.1	6.5	154.2	3.5	79.9	1.5
93.7	6	157.9	3.5	84.8	2.5
86.1	5	131.8	2.5	85.8	1.5
86.7	8	133.6	2	85.4	1
76.7	3.5	106.2	3		
75.5	3	116.5	2		
76.8	8	119	2		
70.9	8	127.2	0.5		
73	7	111.7	0		
71.7	14	118.1	1		
78.1	5	82.2	1		
73.9	6	90.8	1.5		
76.8	8	95.5	2		
73,7	6	97.4	1		
74	5	106.6	1		
67.4	8	100.6	1		
		99.7	2		

After Interval

Mn.		Ge.		Gs.	
73	4	91.4	1.5	86	0
73.4	3	84.2	1	76.4	2
70.4	7	82.2	0	83.7	0
68.4	2	104.9	3	77.1	0.5
68.7	6	91.7	3	82.5	3
70	5.5	88.7	0	77.4	1
70.7	3	83.4	0.5		
69.6	3	81.7	0		
66.7	5	91.5	2		
64.6	11	95.1	3.5		
63.3	6.5	82.5	1		
62.3	8	82.9	1		

TABLE XXIII (Con.)

Second Group, Control Reagents

Before Interval

Day		Bd.		Bh.		Bs. 2		Cf.	
3/3	1	102	7	100	3	100	7	128.4	1
3/5	2	93.4	14+	84.2	6+	87.6	5	112	1
		92.6	13+	74.4	8+	82.8	1	118	1
		87.4	7+	75	5+	75.8	4+	100.8	0
		86.6	5+	78	5	72	2+	102.6	0
		86	5+	76.8	7	70.8	3+	96	0
		80	7	76.4	7	73	2	93.4	1
3/8	3	84.2	5+	79	0	72.8	3+	92.4	1
		81	7	72.4	1	73	3+	88	2+
		77.4	4	80	4+	68.4	2	80.8	0
		73.2	3+	76.2	2	66.4	3	87.2	0
		79	3+	76.2	3+	68.6	4	87	1
		76	4	73.4	4	68.6	0	88.6	1
3/10	4	71.2	3	76.6	4	62.6	1	81.8	0
		67.1	3	74.2	2	65.6	1	78.2	0
		72.6	4	72.4	6	67	5	88.4	1
		71.6	5+	72.4	11	62.8	3	80.8	2+
		72.8	4	75	5+	61.2	3	80.4	0
		68.8	3	74	6	62.4	4	86.2	1
3/12	5	69.4	2	71.8	7+	64.8	3	80.8	1
		66	0	67.4	8	62.6	1	77.8	0
		68.6	3	66.4	8	63	6	76.8	0
		67	7	64.8	13+	67.6	4+	75	0
		66.6	2+	65.4	7	62.6	3	74.8	0
		67.6	3+	66.2	10	60.4	0	74	0
3/15	6	65.6	1	70	7	61.6	4+	73.6	1
		63.2	1+	66.6	6	69.4	1	68	0
		66.2	3+	63	7	60	2	70.4	1
		64.6	5	62.2	5	62.4	3	74	0
		65.4	4	64.6	11	60.4	6	71.4	2
		65.4	2	60.6	5	62.2	4	75.2	0+
After Interval									
	1	64.6	2+	70.4	2	63	2	75.2	2
		62.6	4	62.6	6	58.6	3	65.2	1
		65	2+	62.4	5	60.6	4	69.4	0
		63.8	2	58.0†	4	60.4	6	71.6	1+
		66	4	61.4	5+*	59.6†	2	65.2	1
		65	6	61.4†	8+*	57.6†	4+	62.2	1
	2	62.8	4	64.4	4	58	7	67.6	2
		63.4	4	60	4	58.4	4	64.4	2
		60	5	61.2	7	56.6	6	68	0
		61	5+	61.6	4+	54	4	67	0
		61	3+	59.6	6	54	3	70.4	1
		59.2	7+	57.8	5	55	5	66.2	0
	3	58.6	7	59.6	3	54.8	4+*	65.8	2
		56.8	3	56.6	6+	57.6	3	57	0
		61	7+	59	8+	57.6	5	64.2	0
		60	8	60	5	58.2	3	65.0	2+
		58.6	7	61.6	7	59.2	4	68.6	0

* Over 10 reactions one place late,—a distinct process of reaction which greatly decreases the time.

† Memory of the beginning of the series.

TABLE XXIV

(Text, p. 56)

Reactions on Typewriter (Avg. per 100 per Day) (Control Reagents)

Mm.		Ge.		Gs.	
Before Interval					
90.7	5	141.8	4	87	1
74.1	7.5	116.5	1.3		
74	6.3	96.1	1.5		
After Interval					
70.7	4.5	90.5	1.3	80.5	1
66.2	7	86.2	1.3		

TABLE XXIV (Con.)

Second Group Control Reagents

Bd.		Bh.		Bs. 2		Cf.	
Before Interval							
102	7	100	3	100	7	128.4	1
87.7	8.5	77.5	6.3	77.0	2.8	103.8	0.5
78.5	4.3	76.2	2.3	69.6	2.5	87.3	0.8
70.7	3.7	74.1	5.7	63.6	2.8	82.6	0.7
67.5	2.8	67.0	7.3	63.5	2.8	76.5	0.2
65.1	2.7	64.5	6.8	62.7	3.3	72.1	0.7
After Interval							
64.5	3.3	62.7	4.8	60.0	3.5	68.8	1.0
61.2	4.7	60.8	5.0	56.0	4.8	67.3	0.8
59.0	6.4	59.4	5.8	57.5	3.8	64.1	0.8

Showing Effect of Card-Sorting Practice
(Line thru curve is Avg. of last day before interval)

TRAINED REAGENTS

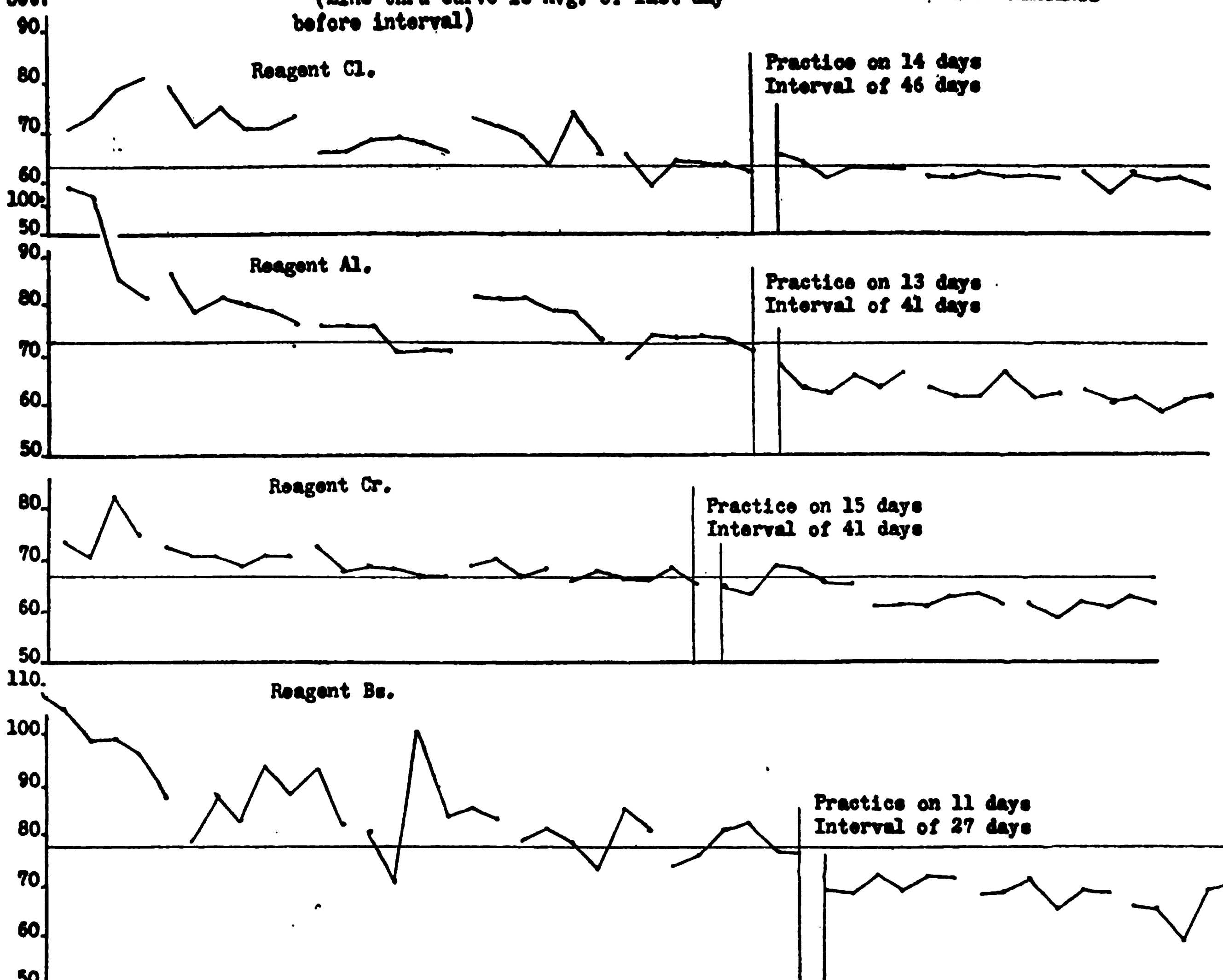


PLATE XIII. (See Text, pp. 53, 56, 58)

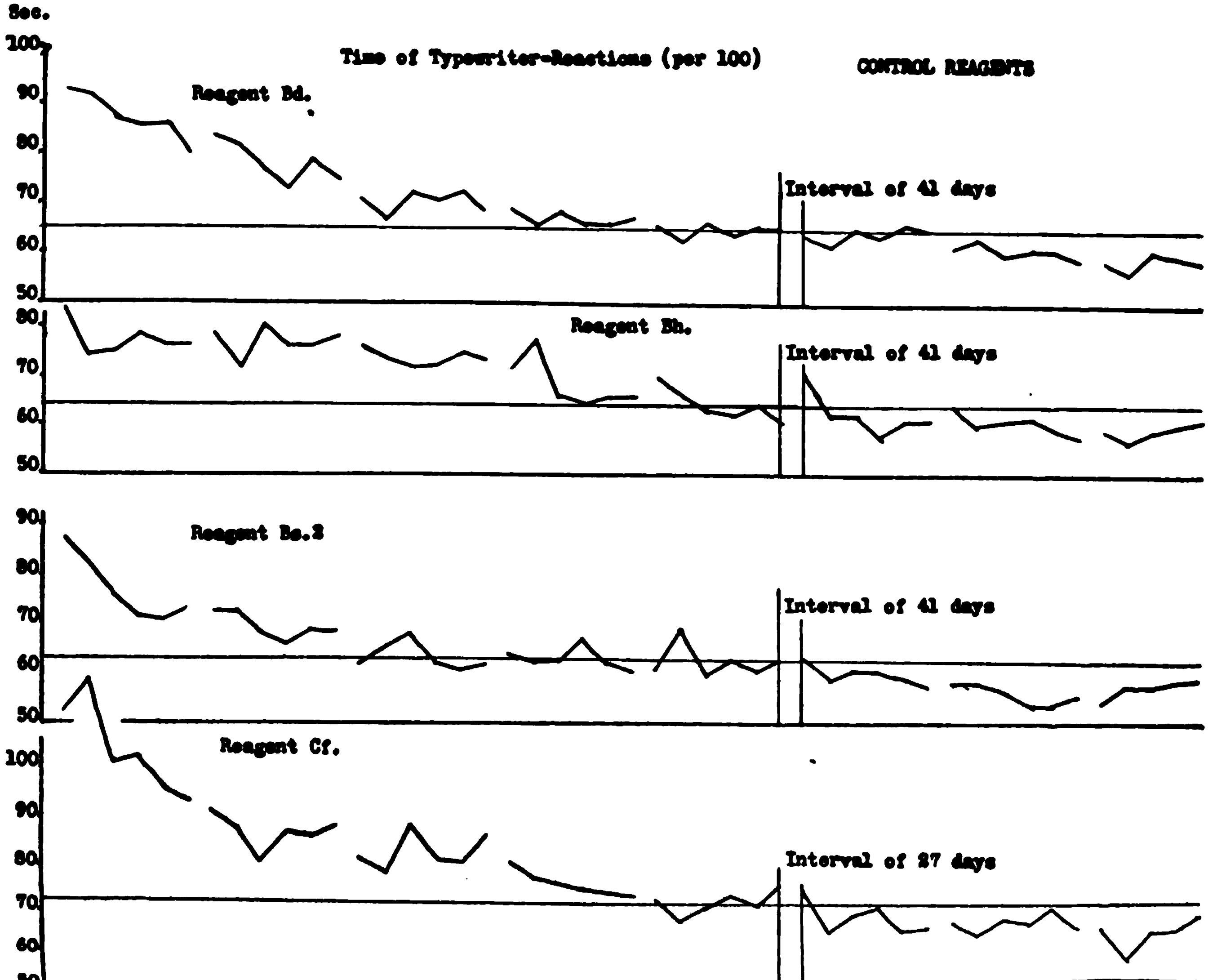


PLATE XIV. (Continued on next page.)

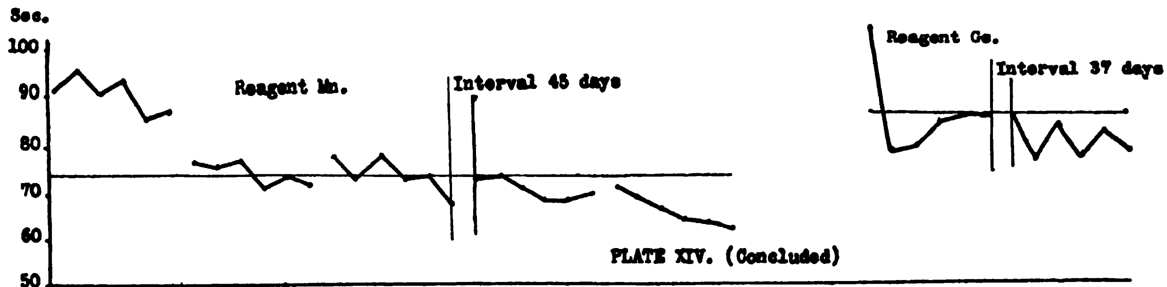


PLATE XIV. (Concluded)

Daily Average of Time of Typewriter-Reactions (per 100)
Showing Effect of Card-Sorting Practice

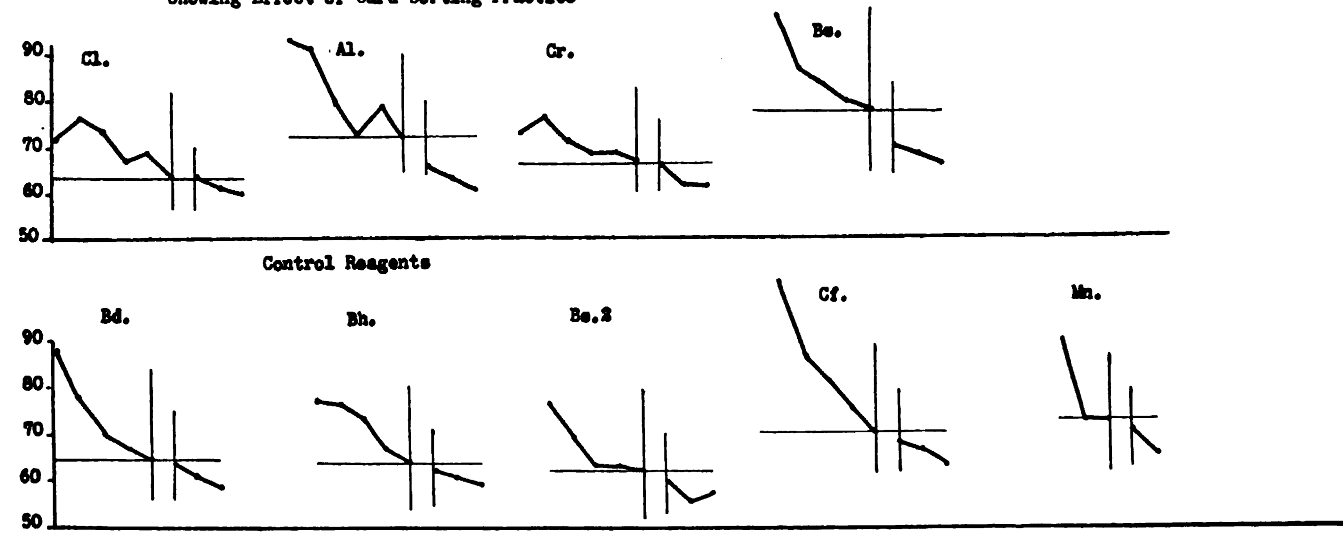


PLATE XV.
(See Text, pp. 56, footnote 58-9)

TABLE XXV
(Text, pp. 53, 54, 56)
Card-Sorting Reaction (per 100)

Cl.		Al.		Cr.		Bs.	
Sec.	Errors	Sec.	Errors	Sec.	Errors	Sec.	Errors
113	0	136.6	2	130.2	0	133.8	0
100.6	0	134	5	122.4	2	127.6	1
111.2	0	119.2	0	108.6	3	117.8	4
103.4	0	116.4	2	112	3	129.4	2
96.8	0	123	1	112.2	2	124.2	0
93.2	1	109	2	103.8	2	111.8	3
99.8	1	103.6	3	96.2	0	115	0
101.8	0	103.4	2	97.2	1	107.5	3
92	0			105.4	2	109.5	4
		101.6	4	100.6	6	104.5	2
89.3	0						
89.4	0	97.6	3	98.4	2	101.4	1
88.6	0	91.6	1	102.6	7	87.4	5
88	0	91.4	1	99	2	100	2
90.4	0	96.2	8	97	1	99.2	2
91.6	0	92.2	3	95.4	2	100.8	2
87.9	0	94.8	4	88.2	0	96	3
93	0			91.8	6	99.2	1
90.6	0	91.8	3	92.4	3	98.4	2
90.4	0	91.6	3	90.6	4	98.5	1
90	1	88	2	88.8	2	100.5	4
91.8	0	89.8	5	93.4	3	96.5	6
93.4	0	88	5	96	2	97.5	3
92.2	0	90.2	3	96.2	5	109	7
85.4	0	91.4	2	89.8	4	103.5	6
94.8	0	87.2	4	95.8	5	97	5
90.4	0	91.4	4	92.4	2	95.5	2
84.5	0	91.8	4	94.8	5	103	3
81.5	0	96	4	95.2	2	102	5
81.5	0	98	9	92.4	1	92.5	1
85	2	100.4	7	89.2	2	89	0
89	0	96.6	4	91.5	1	105	8
85	0	91.8	3	88	3	95.5	1
89.2	1	96	4	92	5	90.5	3
86.4	0	94.8	3	91.5	3	89.5	2
85.5	0	88.4	6	89.2	1	89.5	2
82	0	90.4	4	86.2	6	88	1
79.5	0	89.8	7	97	4	92	5
79	1	94.2	5	97.5	4	90.5	1
81	0			93	2	88	0
83.5	0			96	5	87	1
82	0			93.5	6		
81	0			88.5	6		
				91.5	2		
				95.5	14		
				93.5	2		
				94	7		
				92.5	4		
				92	4		
				96	5		
				92	8		
				92	4		
				91	3		

TABLE XXVI

(Text, p. 53)

Card-Sorting Reaction (Avg. per 100 per Day)

Cl.		Al.		Cr.		Bs.	
Sec.	Errors	Sec.	Errors	Sec.	Errors	Sec.	Errors
106.8	0	135.3	3.5	126.3	1	127.2	1.8
107.3	0	117.8	1	110.3	3	118	1.5
97.9	0.5	116	1.5	102.4	1.3	109.1	1.5
90.6	0	102.9	3	102	4.3	97	2.5
89.1	0	94.2	3.3	94.9	1.3	98.6	2
90.8	0	93.5	3.5	90.9	3.8	98.2	3.5
90.2	0.5	90.5	2	93.9	3.5	106.2	6.5
90.7	0	88.9	5	94.6	3.5	99.4	3.8
92.6	0	90	3.3	90.8	1.5	95.5	2.3
83.1	0.5	96.5	6	90.8	3	89.4	2
87	0	94.2	3.5	87.7	3.5	89.4	1.8
87.3	0.5	95.4	3.5	95.9	3.8		
81.5	0.3	90.7	5.5	92.8	6.2		
81.9	0			93.1	5.3		
				91.5	3.5		

TABLE XXVII

(Text, pp. 57, 58)

Comparison of Gains Between Training Periods
Typewriter-Reaction

	Training Reagents (4th and 5th Days, in Practice.)				*Control Reagents* (4th and 5th Days after Interval.)	
	Cl.	Al.	Cr.	Bs.	Mn.	Ge.
Avg. of 2nd and 3rd Days......	70.5	76.6	70.0	86.0	74	105.5
Avg. of 4th and 5th Days......	66.1	76.0	67.9	79	68.4	88.4
Gain	4.4	0.6	2.1	7.0	5.6	17.1
% Gain	6	0.8	3	8	7	16
Avg. last two Days before Card Practice	66.1	76.0	67.9	79		
First two after	62.3	64.0	64.3	69.9		
Gain	3.8	12.0	3.6	9.1		
% Gain	6	16	5	12		

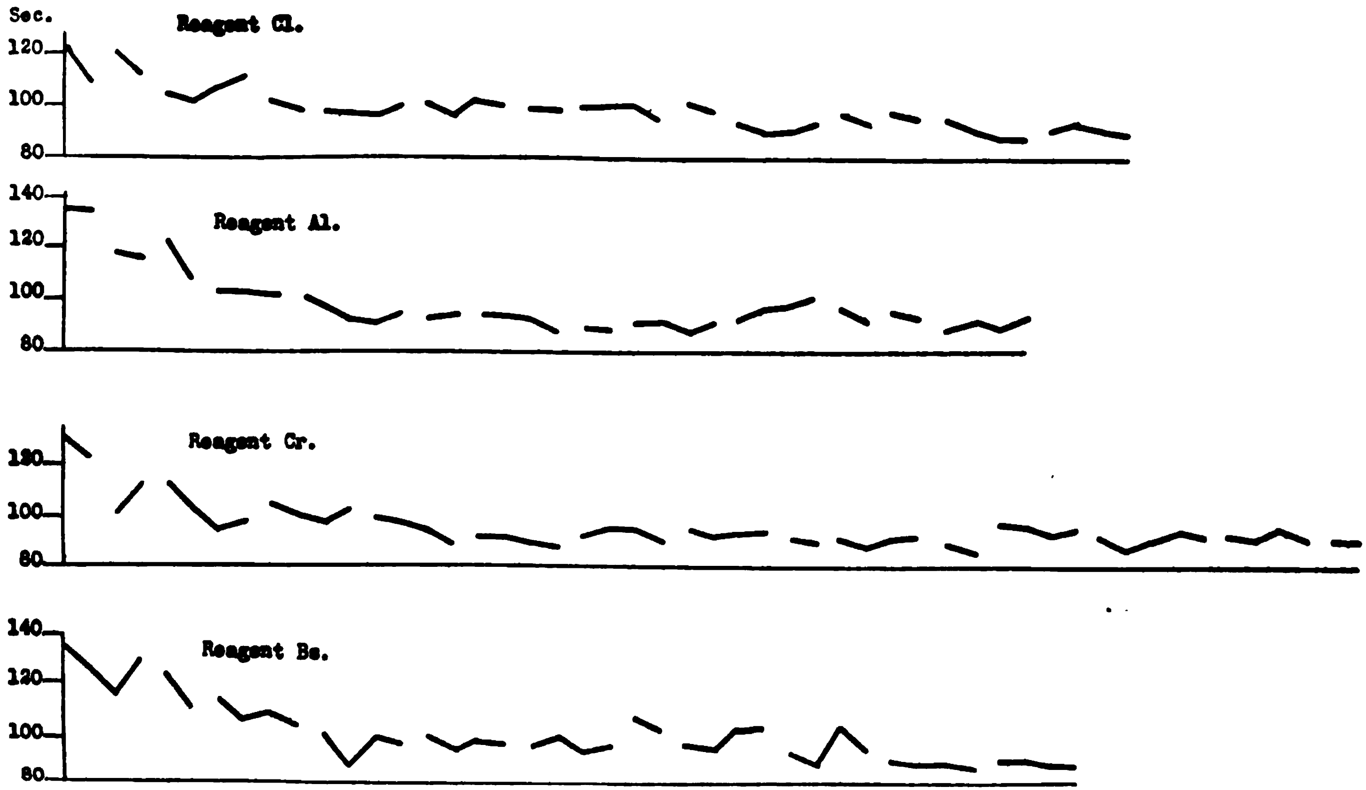


PLATE XVI. Practice Curves of Card-Sorting. Time per 100 reactions. (From Table XXV.)

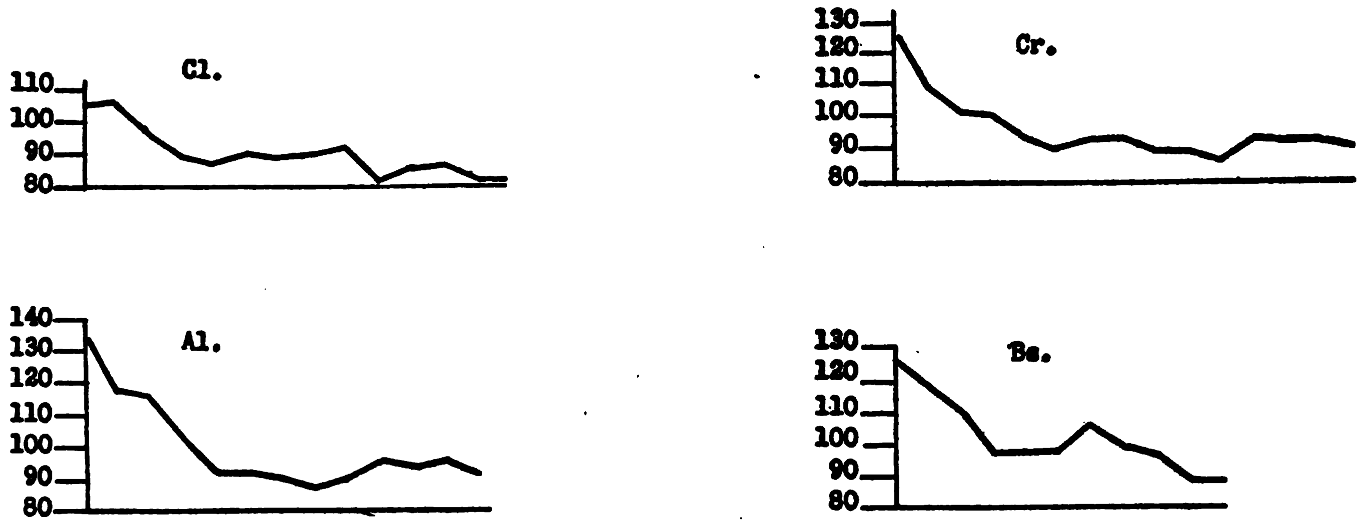


PLATE XVII. Practice Curve. Averages for successive days. (From Table XXVI.)
(See Text, p. 53)

TABLE XXVIII

(See Text, footnote pp. 58-9)

Time per pack of 50 cards, sorted by suit into four compartments, showing the influence of practice in the typewriter-reaction.

Before Interval

	Regular Reagents								Control Reagents			
	Bd.		Bh.		Bs. 2		Cf.		Cn.		Sn.	
	55	0	55.4	0	52.4	0	62.4	1	57.4	0	48.8	0
	57.5	1	51	1	54.6	0	70	0	52.4	0	50.6	1
	55	0	52.6	1	50	0	67	0	53.6	1	49	0
	50	0	48	1	52.6	1	67	0	48	1	50.6	1
Total	217.5	1	207.0	3	209.6	1	266.4	1	211.4	2	199.0	2

After Interval

	Bd.		Bh.		Bs. 2		Cf.		Cn.		Sn.	
	56.6	1	51	1	52.8	5	61.4	0	60	1	51.4	0
	54.2	1	50	2	53.4	5	56.4	0	55	2	49.8	0
	52	0	49.8	3	52.2	3	57	0	53.8	1	50.6	0
	52	4	46.8	3	50.6	3	57	0	52.6	5	52.4	0
Total	214.8	6	197.6	9	209.0	16	231.8	0	221.4	9	204.2	0
Diff.	—2.7		—9.4		—0.6		—34.6		+10		+5.2	
%	—1.2		—4.5		—0.3		—13.0		+4.7		+2.6	

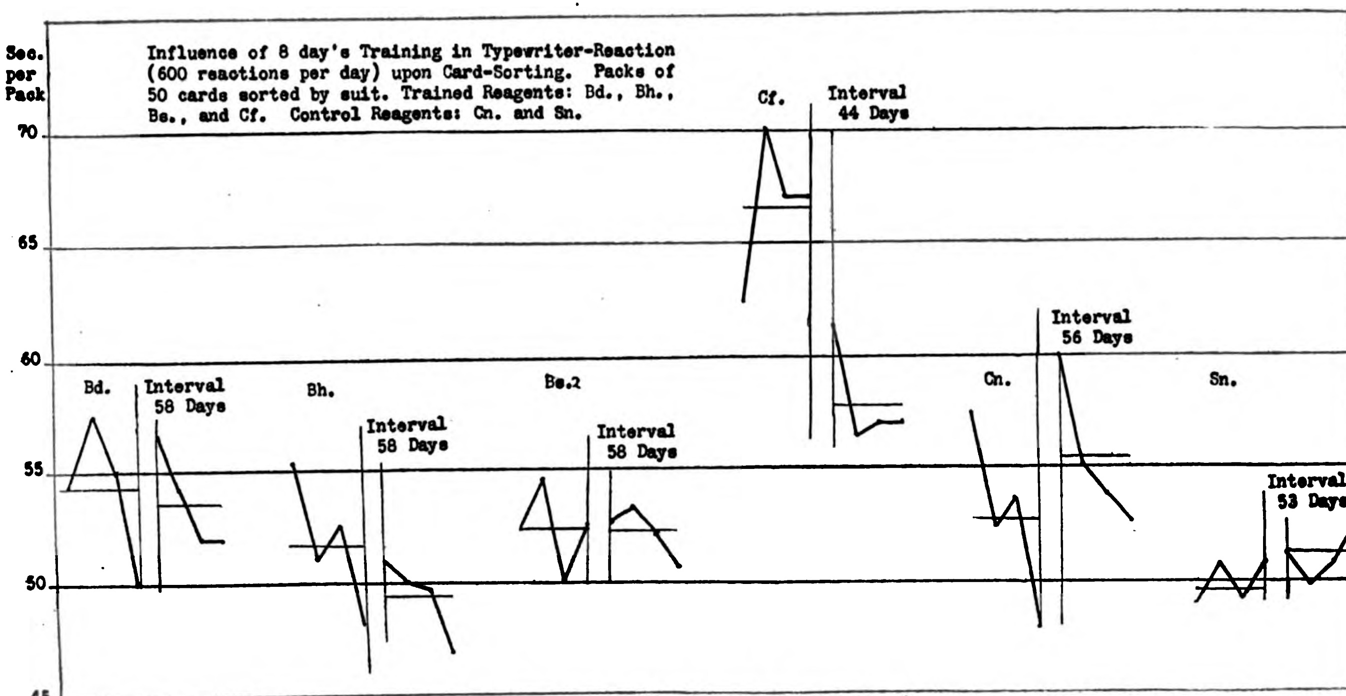


PLATE XVIII. (See Text, footnote p. 59.)

APPENDIX B

(Presenting data relevant to the Experiment on Attention, pp. 76-173.)

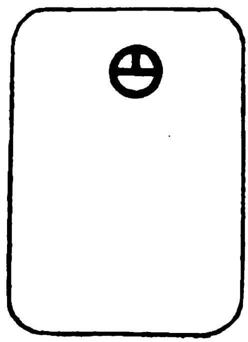


FIG. 1
Symbol on cards

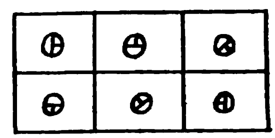


FIG. 2. (See p. 76) Arrangement of compartments in cabinet for card-sorting.

Cardsorting

Instructions to reagents

1. This is a test in "reaction with discrimination and choice." On each of the packs of fifty cards the time and errors will be recorded. Speed, therefore, should be aimed at, yet the sorting should be accurate. Time will be saved if you get a dependable mental scheme of the compartments rather than directly matching the cards, which, although necessary at first, makes sorting wait upon the eye.

2. In the final introspections of the day note:
   (a) Any special hindrances or helps to the sorting,
   (b) Your mental scheme, if any,
   (c) Any development or change in your scheme,
   (d) What demanded attention most? Any tendency to name or pronounce?
   (e) Whether the sorting is fatiguing,
      (1) Any bodily strain,
      (2) Any mental strain,
   (f) Whether sorting is agreeable or otherwise,
   (g) Any change in these respects from previous introspections. (Applicable only after the first day.)

3. In introspections noted between packs mention briefly a few of the more important points about the process of sorting that occur to you.

4. Look over the cards on the cabinet so you will be able to distinguish the symbols readily.

5. The procedure will be:
   (a) Arrange first pack conveniently in hand, and take position comfortably before the cabinet.
   (b) Throw on the table the blank, at announcement of "Go!"
   (c) Sort cards, aiming for speed and accurate work. As last card leaves hand announce "Now!"
   (d) Note brief introspections.
   (e) Like procedure with remaining three packs, taking them in order.
   (f) After the last pack of the day, note your introspections in fuller form.

Fig. 3 (See p. 76)

aatanetntaeneaatanetntaeneeaeneatntenatta tanetnaene

FIG 4. Sample series of stimuli used in the typewriter-reaction (see pp. 52, 76).

Poets	Philosophers	Statesmen	Scientists	Musicians
Homer	Plato	Pitt	Faraday	Beethoven
Virgil	Socrates	Gladstone	Darwin	Wagner
Shakespeare	Aristotle	Washington	Huxley	Mozart
Milton	Kant	Jefferson	Watt	Hayden
Browning	Locke	Lincoln	Tyndall	Bach
Tennyson	Hume	Webster	Agassiz	Mendelssohn
Goethe	Hegel	Roosevelt	Galileo	Handel
Whittier	Pythagoras	Napoleon	Helmholz	Verdi
Poe	Spinoza	Bismark	Newton	Paderweski
Longfellow	Descartes	Burke	Ohm	Paganini

Fig. 5. The names of men in the classes used for Controlled Reaction. (See p. 77)

Series 1	Series 2	Series 3	Series 4	Series 5
Homer	Darwin	Socrates	Aristotle	Browning
Pitt	Virgil	Shakespeare	Hayden	Lincoln
Beethoven	Wagner	Huxley	Kant	Bach
Faraday	Gladstone	Milton	Watt	Tyndall
Plato	Mozart	Washington	Jefferson	Locke

Series 6	Series 7	Series 8	Series 9	Series 10
Hume	Roosevelt	Napoleon	Verdi	Descartes
Agassiz	Galileo	Goethe	Bismark	Ohm
Mendelssohn	Hegel	Helmholz	Paderweski	Paganini
Webster	Handel	Whittier	Poe	Burke
Tennyson	Pythagoras	Spinoza	Newton	Longfellow

Fig. 6. The series of names as presented. (See p. 77)

	(a) Intervals		(b) Series				
No.	Scale	Intensity[1]	1, 2	3, 4	5, 6	7, 8	9, 10
1.	20.16°	.5	1	2	3	4	5
2.	23.57	.7	7	8	9	1	2
3.	25.06	.8	5	6	7	8	9
4.	26.48	.9	2	3	4	5	6
5.	27.83	1.0—Norm	9	1	2	3	4
6.	29.12	1.1	4	5	6	7	8
7.	30.35	1.2	8	9	1	2	3
8.	32.68	1.4	3	4	5	6	7
9.	34.85	1.6	6	7	8	9	1

[1] From Fechner: Psychophysik. S. 181.

Fig. 7. Intervals of intensity, and series as presented in Sound Discrimination. In the Series, No. 2 is the reverse of No. 1. (See pp. 77, 78, 188)

Greater,	>
Less,	<
Like,	|||
Doubtful,	?

FIG. 8. Symbols used in recording judgments in Sound Discrimination. (See p. 78)

Series 1	2	3	4	5
3	4	2	2	1
1	3	4	1	4
4	1	1	3	2
2	4	3	2	3
3	2	2	4	2
2	3	4	2	1
4	2	2	3	3
1	4	3	1	4
3	1	1	4	2
4	3	2	2	1

Intensities[1]

$1 = 10^\circ = 0.12$
$2 = 25^\circ = 0.80$
$3 = 40^\circ = 2.10$
$4 = 60^\circ = 5.00$

[1] From Fechner's Psychophysik, I:181).

FIG. 9. Series of sounds in the test on Memory of Sounds. (See p. 78)

Series of letters and figures

1 (a)	(b)	2 (a)	(b)	3 (a)	(b)	4 (a)	(b)	5 (a)	(b)
K	4	C	5	P	7	G	6	L	8
S	7	V	8	H	1	L	9	G	2
B	5	J	6	Z	8	C	7	M	9
M	2	B	3	K	5	H	4	P	6
F	6	S	7	B	9	P	8	S	1
P	1	H	2	S	4	F	3	B	5
H	3	W	4	P	6	M	5	K	7
C	8	T	9	C	2	B	1	C	3
L	2	D	3	G	5	S	4	H	6
G	9	K	1	N	3	K	2	P	4

FIG. 10. The series of (a) consonants used in the test on Memory of Consonants, and the series of (b) Digits used in the test on Memory of Numerals; also (c) the pairs presented in the test on Memory of associated Pairs. (See p. 79.)

FIG. 11. The series of symbols used in the test on Memory of Visual Signs. (See p. 79.)

FIG. 12. Reproduction of size and style of letter and spacing used in tests on Learning 12-Consonant-Rectangles. (See pp. 80, 82.)

M—— R ——C
G—— L ——D
C—— M ——V
W—— N ——T
S—— W ——N
Q—— R ——L
N—— T ——R
S—— W ——R
B—— R ——N
W—— S ——M

FIG. 13. The letters used in the test on Word-Completion. (P. 80.)

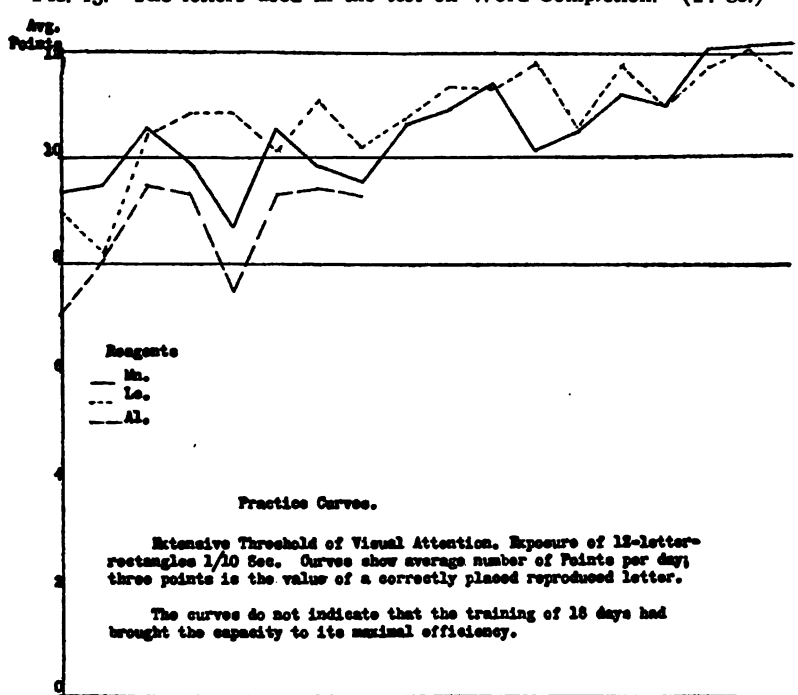


FIG. 14. (See text, pp. 83, 93)

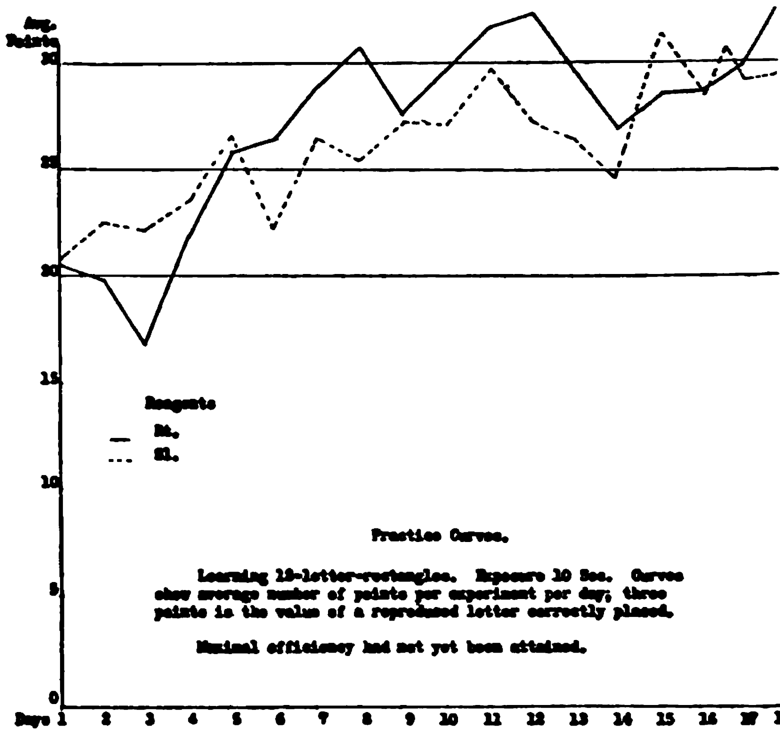


FIG. 15. (See text, p. 94)

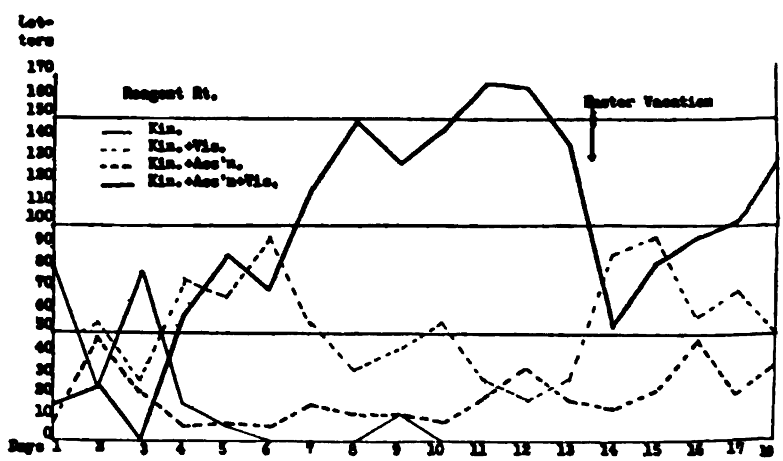


FIG. 16

Analysis of Rt.'s Practice Curve in Learning 12-letter-rectangles, accord-

ing to complexity of process, showing change in complexity during practice. The curves show the number of letters reproduced from rectangles according to the imagery from which they were recorded; *e.g.*, on the first day 80 letters were recorded from rectangles upon which the Kinaesthetic (verbal) imagery alone was used, 40 letters from rectangles upon which Kin. and Visual imagery were coördinated, 17 letters from rectangles for which the three-fold coördination of Kin. + Associations + Vis. imagery was used. (See text, pp. 95, 176.)

At the beginning most of the work was done in Kin. A. imagery which as a single-fold method disappeared on the 6th day. The two-fold method was dominant on the 4th, 5th, and 6th days. From the 7th day the three-fold and four-fold coördinations predominated. The course of practice is toward greater complexity of the process.

Easter vacation caused a lapse to the status of learning of the 6th day, after which the same development in complexity of coördination takes place as that on the 7th and 8th days.

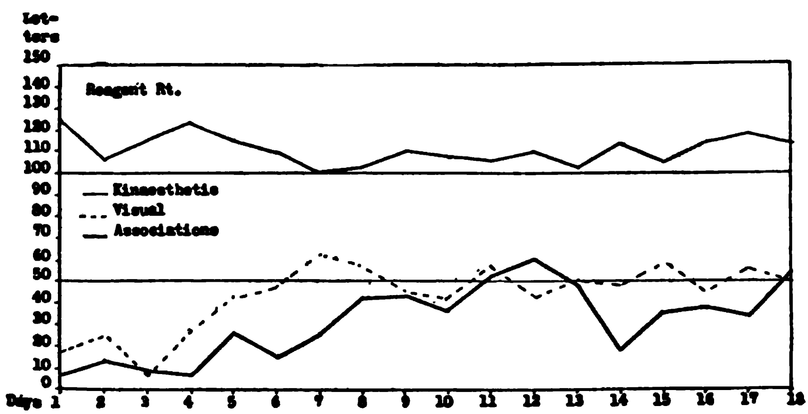


FIG. 17

Analysis of Rt.'s Practice Curve in Learning 12-letter-rectangles, according to the number of letters reproduced from each kind of imagery during the day, disregarding the complexity of method in coördinations, *e.g.*, on the first day 125 letters were reproduced from Kinaesthetic (Verbal) imagery, 18 from Visual imagery, and 8 from Associations. (See text, p. 174.)

Associations for Rt. were usually visual images of words, as "Chemically Pure" for holding the letters C P.

It is evident that the principal rise in the practice curve is caused by the growing frequency of Visual and Association letters, *i.e.*, by the growth in the process of the auxiliary forms of imagery. The letters reproduced on the 12th day are similar to those reproduced on the 3d day in that they are alphabetic symbols; in the mind of the reagent, however, they differ greatly in kind of letter—they are more dominantly visual and visually word-bound symbols, less rote-letters in the muscles of the tongue.

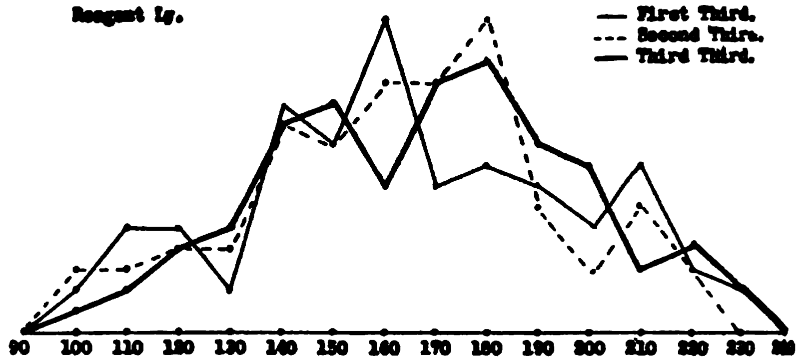


FIG. 18

Curves show distribution of Reaction to Sound in the first, second and third thirds of Ly.'s training (1100 reactions); only the reactions with the Morse key at 100-gram tension being chosen (270 reactions). Reactions from 91 to 100 sigma are plotted on 100. (See text, p. 101).

Practice-effect involved change in processes.

APPENDIX C

Scoring the 12-letter-rectangle

If a single score is to measure the power of reproduction, it must give value to a reproduced letter when it is misplaced in the record; and it would seem that this value should be less than the value given to a correctly placed letter, and should vary with the degree of spatial reproduction as indicated by the amount of misplacement. Any system of values, nevertheless, is arbitrary, since it will favor some methods of learning and reproduction more than others.

Let the following scheme represent the relative positions on a 12-letter-rectangle:

j	c	b	a
k	g	f	d
l	i	h	e

a = Correct position, and may be in any space on the card.
b = Adjacent space on the line.
c = Second remove on the line.
d = Adjacent space in the column.
e = Second remove in the column.
f = Space adjacent at corner.
Etc.

If the reproduced letter belongs in position *a*, in the above scheme, (and that may be in any space on the card), we may compare several ways of scoring noticed in the text (p. 80):

Points		Text (1)[1]	Winch[2]	Smith[3]	Text (2)[4]
3	=	a	a	a	a
2	=	b, c, j	b, d	b, c	b, d, f
1	=	d, e	c, e	d, e, f, g, h, i, j, k, l	c, e, g, h, i, j, k, l
0	=	f, g, h, i, k, l	f, g, h, i, j, k, l	——	——

A rote method of learning by the line would be favored by Text (1) and Smith, for its misplacements would be more frequently made within the line; by the column, by Winch, for a similar reason. A visual reproduction would be favored by Text (2), since *f* is a proximate location; and vague reproduction by Smith and Text (2), since they offer no zero value for reproduced letters. In partial justification of the zero value it may be urged that over half of the consonants of the alphabet are on the card, and that mere guessing would raise the score of reproduction in over half of the guesses, especially when some of the consonants are known and the chance for correct guesses is consequently increased. If the letters are really reproduced, however, they should contribute to the score.

Perhaps the assignment of values should not be made until all the misplacements of a given reagent are tabulated and the various kinds of misplacement are compared with degrees of reproduction as revealed by an analysis of his mental processes; then the values could be assigned with reference to the degree of reproduction, which might be found to decrease with the frequency of the kinds of misplacement.

---

[1] P. 80.
[2] Winch: Br. Jr. Psychol. 1: 129; also Whipple's Manual (1st ed.) p. 369.
[3] Smith: Mind. N. S. 4: 52. The writer's interpretation of the rather indefinite text is given here.
[4] P. 187.

Such a tabulation was made of the results from 20 experiments by each of ten reagents in Tests 13 and 17, and it was found that although there was considerable variation between the different reagents in the number of letters misplaced in 20 experiments (12-44, with an average of 15% of all reproduced letters in Test 13; 7-38, with an average of 29% of all reproduced letters in Test 17), within each test large individual variation in the kind of misplacing involved a few kinds only (in Test 13, misplacings *c* and *d;* in Test 17, *b, d,* and *f*). If frequency as found in the aggregate results would not call for a division of these particular kinds of misplacing into different classes for evaluation, a system of evaluations upon the basis of aggregate results might be available for general application. This condition is fulfilled, as may be seen from the following tables, but it necessitates a separate system of evaluations for each of the two tests.

All of the misplacings of all of the reagents in each test were tabulated and calculated with the following aggregate results (reduced to the average number of letters so placed in one experiment):

Test 13				Test 17			
j	c	b	a	j	c	b	a
.01	.215	.42	6.97	.015	.065	.285	2.245
k	g	f	d	k	g	f	d
.015	.085	.11	.26	.020	.080	.160	.200
l	i	h	e	l	i	h	e
.01	.025	.03	.035	.000	.045	.015	.045

But these amounts show the actual distribution of misplacings; if we assume that a misplacement which occurs more frequently should be penalized less in the score measuring reproduction than one which occurs less frequently (introspections are not full enough to indicate clearly whether it should), our system of arbitrary values could not be taken from the distributions shown above for the reason that the chance of making some misplacings is much greater than that of making others; *e.g.*, in chance guessing the misplacement *f* would occur 24 times to *l* 4 times. We should need this distribution as modified by the relative chances of the misplacings.

The Ratio of Recorded to Chance Misplacings would seem to meet this need. If position *a* is moved systematically over the card, occupying in turn every one of the 12 spaces, there would aggregate 132 possible misplacings distributed over the lettered relative positions as follows: 24, f; 18, b; 16, d, g; 12, c, h; 8, e, i, k; 6, j; 4, l. According to these chance values of the positions the 1.27 misplacings (per experiment) of Test 13, and the 0.93 misplacings per experiment of Test 17, could be distributed; position *d*, in Test 13 would then have the value of .153 instead of .26, the ratio of its actual occurrence to chance occurrence being 1.70. These ratios calculated for all the relative positions are presented in the following table:

Ratio of Recorded to Chance Misplacing.

Test 13				Test 17			
j	c	b	a	j	c	b	a
0.17	1.87	2.44		.35	.77	2.24	
k	g	f	d	k	g	f	d
.20	.56	.48	1.70	.35	.71	.95	1.77
l	i	h	e	l	i	h	e
.27	.33	.26	.46	0.00	.80	.18	.80

But it might be objected that we do not still have a measure of the relative frequency of the respective misplacings, since owing to the reagent's direction of his attention to one portion of the card rather than to another, the letters which in reproduction were misplaced may not have been distributed evenly over the 12 positions. Calculation sustains the objection so far as it suspects irregular distribution over the positions: The range in Test 13 is 13 (in the 1st position) to 33 (in the 7th position); in Test 17, 7 (positions 9 and 11) to 41 (position 4). When the actual chances for the respective misplacings are calculated, however, the results showing relative frequency of misplacings are substantially the same as in the tables above:

Ratio of Recorded to "Actual" chance misplacing.

Test 13				Test 17			
j	c	b	a	j	c	b	a
.20	1.87	2.33		.30	.77	2.39	
k	g	f	d	k	g	f	d
.22	.53	.44	1.67	.33	.69	.96	1.71
l	i	h	e	l	i	h	e
.32	.35	.27	.49	.0	.86	.21	.86

And if instead of pooling the results of 20 experiments by each of a dozen reagents we use the 450 experiments (like Test 17) by a single reagent (Mn.), in which the habits of attention may be expected to be more uniform and consequently more disturbing to our calculation on the basis of "regular" chance, the range in irregular distribution being from 4 (position 10) to 47 (position 4), and the number of reproduced letters misplaced being 242 (5%), we get the following remarkable approximation to the ratios with "regular" chance distribution:

Ratio of Recorded to

"Regular" Chance Misplacing				"Actual" Chance Misplacing			
j	c	b	a	j	c	b	a
.28	.41	3.22		.26	.41	3.32	
k	g	f	d	k	g	f	d
.55	.62	.92	1.18	.52	.61	.96	1.19
l	i	h	e	l	i	h	e
.27	.34	.27	.41	.26	.34	.28	.41

There is little doubt therefore that these tables furnish us with fairly reliable relative frequencies of the respective misplacings in these two tests. Upon the assumptions that the more frequent misplacing should be penalized less in the score, that three points shall be the value of a correctly placed letter, that in the interest of facility fractional values shall be avoided, and that great injustice is not likely to result in striking an approximate balance between over-evaluation and under-evaluation of respective misplacings, it would seem that the following values might be recommended :

Test 13. (Exposure 10 sec.)	Test 17. (Exposure 1/10 sec.)
3 = a	3 = a
2 = b, c, d,	2 = b, f, d,
1 = all others.	1 = all others.

The arbitrariness of forcing this qualitative difference in reproduction into a quantitative difference, has already been remarked. The *g* or *i* misplacings are only by courtesy to the strenuous statistician to be regarded as possessing one-half the reproductive value of misplacings *b* or *d*, and one-third the reproductive value of a correctly reproduced letter. Disregarded also is the partiality to visual memory: letters retained in vivid visual imagery keep their relative positions; letters reproduced from equally vivid auditory or kinaesthetic imagery may be free from either temporal or spatial order.

The values listed under Test 17 are those employed in our Text (2) method of scoring. It will be remembered that exposure of the card was about a tenth of a second; it is for this reason that *f* is a proximate position.

Upon re-scoring Tests 13, and 17, the average scores were found to range in points from 15.5 to 27.3, and from 4.1 to 9.1, respectively, and to increase only 0.36, and 0.61 points, respectively. Our Test (1) method was unsatisfactory, therefore, principally because it is an arbitrary method, and, like many mental test methods of measurement, confuses process and product. Its difference from other methods of scoring, equally arbitrary, has no bearing on our treatment of results, which, the reader has noted, is principally qualitative.

APPENDIX D

Influence of Subliminal Differences upon Judgment in Stimulus Comparison (Discrimination) (See Text, p. 185)

In experiments on Sensible discrimination in which the Method of Constant Changes, Right and Wrong Cases, is employed, it is commonly observed that, if the steps between stimulus-differences are small enough, R Cases (correct judgments on "greater" or "less") fall off regularly with the decrease in stimulus-difference even when these steps fall below the difference which is conventionally designated as the "Least Noticeable Difference." (50% R Cases. *vid.* Külpe: Outlines of Psychology, p. 69; or Titchener: A Text-book of Psychology, p. 213). This influence of "subliminal" differences upon judgment in stimulus comparison may be illustrated from our own data, if we aggregate the judgments of all reagents upon each of the intervals (stimulus-differences) in the respective tests and practices in Sensible Discrimination.

If we call the interval between the variable of least intensity and the norm the first, and the interval between the variable of greatest intensity and the norm the last (7th or 9th), we get the following table of R Cases, in per cent:

Interval	a	b	c	d
1	77	92	85	78
2	67	65	57	70
3	49	50	31	59
4	39	31	23	38
5 = Norm				
6	59	49	41	41
7	79	55	53	62
8		76	74	65
9		84	84	75

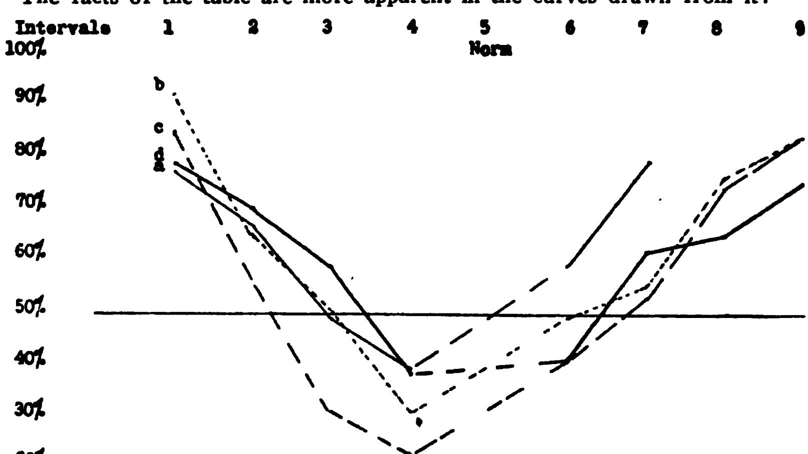
a = Discrimination of Brightness (180 judgments on each interval, 14 reagents) 1904-5. (Text, pp. 42ff.)

b = Discrimination of Sound with Sound Pendulum (160 judgments on each interval, 16 reagents) 1910-1911. (Text, pp. 134ff.)

c = Discrimination of Sound with Sound Pendulum (120 judgments on each interval, 12 reagents) 1911-1912. (Text, pp. 206ff).

d = Discrimination of Sound with Fall Phonometer (96 judgments on each interval(2 reagents) 1911-1912. (Text, 188ff).

The facts of the table are more apparent in the curves drawn from it:



The "Least Noticeable Difference" is 50% R Cases.

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MADISON BENTLEY, University of Illinois (*Index*)

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PREFACE

The work reported in this monograph was carried out at the request and with the coöperation of the Committee on Measurement of Efficiency of Schools for the Deaf representing the Conference of Superintendents and Principals of American Schools for the Deaf, composed of Richard O. Johnson, Chairman, Superintendent of the Indiana State School for the Deaf; J. W. Jones, Superintedent of the Ohio State School for the Deaf; Dr. A. L. E. Crouter, Superintendent of the Pennsylvania Institution for the Deaf (Philadelphia); Augustus Rogers, Superintendent of the Kentucky State School for the Deaf, and Walter M. Kilpatrick of the American School for the Deaf, Hartford, Conn. The writers take great pleasure in acknowledging here the great kindness and courtesy shown to them by the superintendents, principals and teachers of the three schools in which the tests were given. They feel greatly indebted for the coöperation and help given by the educators and teachers whom it was their privilege to meet. In particular they wish to thank here Superintendent Richard O. Johnson, Dr. A. L. E. Crouter and Superintendent J. W. Jones who made this work possible.

Rudolf Pintner,
Donald G. Paterson.

Columbus, October, 1915.

LEARNING TESTS WITH DEAF CHILDREN

The learning ability of the deaf child, as tested by psychological methods, forms the subject matter of this monograph. The tests chosen for this purpose were the Digit-Symbol and Symbol-Digit Tests.[1] It is not claimed that these two tests alone can give an absolute measure of any particular individual's learning ability; but it is our opinion that where large numbers of children are tested, as in this investigation, a fairly definite view of the learning ability of the whole group may be attained.

These tests were chosen for two reasons. In the first place, a considerable amount of work with hearing children has already been done with them, and valuable norms for hearing children have been published by Pyle. These norms form an excellent means of comparison between deaf and hearing children, and they will be referred to repeatedly in the body of the work. In the second place, language is not required in the performance of these tests. This is a desideratum in dealing with deaf children, inasmuch as the language ability of the deaf child is considerably below that of the hearing child. Learning tests involving language would be totally unsuited for the purpose of comparing deaf children and hearing children, because the deaf child is cut off from language experience, due to his inability to imitate the audible sounds of spoken language and is therefore deprived of normal social intercourse. It is the learning of language that forms the greatest obstacle in the education of the deaf child. We believe, therefore, that the choice of our two tests was happily made, as they can be administered and performed without the aid of spoken or written language.

Method of Procedure

The tests were given as class tests. The Digit-Symbol test was always given first by one of the writers, and the Symbol-Digit

[1] G. M. Whipple, Manual of Mental and Physical Tests, Baltimore: Warwick & York, 1910, pp. 350-355. Also, W. H. Pyle, The Examination of School Children, New York: The Macmillan Co., 1913, pp. 18-22.

test by the other followed. This insured uniformity of procedure in each test. In two schools these two tests were given on the same day; in the other school about two months elapsed between the Digit-Symbol and the Symbol-Digit test.

The method of giving the test, as described by Whipple or Pyle, could not naturally be followed in dealing with deaf children. Oral instructions would have been of no avail. Written instructions would have been too difficult to be comprehended by the deaf children, owing to their difficulty with language, and if such had been used would at any rate have made the test primarily a test of comprehension of language and secondarily a learning test. Such a procedure would have increased the difficulty of the test enormously for the deaf children and made any comparison with the norms for hearing children worthless. We, therefore, resorted to a description of the test on the blackboard, and an explanation of what was required by actually performing the operations in front of the class. This is similar to the method suggested by Whipple for giving the test to very young children. The key to the test as printed on the top of the test sheet was drawn on the board, *i.e.*, the nine circles with their appropriate symbols and digits. Underneath this, two lines of the test, similar to but not the same as on the sheet, were drawn, showing the numbers or digits at the left hand side and the blank spaces to be filled in on the right. By natural gestures the experimenter showed how each symbol or digit corresponded to the appropriate blank space, and then went through the motions of looking for the corresponding symbol or digit in the key above, of bringing it down and filling it in the blank space. The experimenter then asked one of the children to come to the board and fill in the next blank space. If the child did not understand he was shown how to do it correctly. Similarly with the rest of the children in the class. In almost every class, with the exception of a few of the higher and brighter classes who obviously understood what was wanted after ten blanks had been filled in by ten pupils, every single child in the class took his turn at the board. Sometimes, indeed, the child was at the board five minutes or more, being instructed how to fill in the blanks. Every effort was made to give all the children the

best possible opportunity to understand what was required. It was the opinion of the superintendents and teachers that this opportunity was given to each child. Of course, in the very lowest grades and with the very dull children, lack of comprehension was obvious from their work, although each one was given a trial at the board and guided through the appropriate movements of filling in the blanks. After this explanation on the board, the children were shown one test sheet held up in front of the class by the experimenter and told that it was the same as the one drawn on the blackboard. The experimenter pointed to the key at the top, the symbols or digits down the sides and the blank spaces to be filled in. The children were told to work as quickly as possible. The test sheets were then passed around and kept face downwards until the signal to begin was given. At a signal all turned over the sheets and worked until the signal to stop was given. Five minutes was the time allowed, except that in the lower grades eight minutes was the time-limit.

Our method of giving the test, as will be seen from the above, differs to some extent from the method employed with hearing children. The greatest difference lies in the fact that the symbols and digits used on the test sheet were before the children on the board from ten to twenty minutes before they started to work. This does not seem to have been the method employed by Pyle as far as can be determined from the description of his procedure. The deaf children had thus this much time during which associations between the digits and symbols could be formed, which would give them considerable advantage over the hearing children. We do not believe that many, if any, of the children set to work to memorize the digits and symbols during this preliminary period of explanation. Most of them were absorbed in the experimenter's explanation and in watching the other children at work at the board. Nevertheless, some familiarity with the digits and symbols must have been attained by the child before beginning the test proper. This, owing to the nature of the case, was unavoidable, and we considered it preferable to setting the children to work without adequate explanation, or without being certain, as we were with our procedure, that almost every child understood

what was required of him. If the hearing children as tested by Pyle had been given the same advantage as the deaf children, the norms for the hearing undoubtedly would be higher, so that in our comparison between the deaf and hearing, it is the deaf child who has the advantage. We feel confident that our estimate of the deaf child's ability on these two tests is most certainly not too low. It is, probably, a little too high.

The Numbers Tested

These tests were carried out in three state schools for the education of the deaf. These three schools we shall designate A, B and C. In all of the schools it was our aim to test as many children as possible. The usual procedure was to begin with the higher classes and to continue down to the lower grades. Only the most elementary classes in each of the schools were omitted, since it was found impossible for the children in those classes to understand the requirements of the tests. It was the aim of the writers to include as many deaf children as possible in the investigation. In school A 351 children were given the Digit-Symbol test and 416 children the Symbol-Digit test. In School B 227 children were given the Digit-Symbol test and 228 children the Symbol-Digit test. In school C 413 children were given the Digit-Symbol test and 405 children the Symbol-Digit test. The ages of the pupils ranged from 8 to more than 20 years. The oldest pupil was about 26 years of age. In our classification of the children according to age we have grouped all those above 18 years old under the heading of adults. This was done because norms for hearing children for the separate ages above 18 are not available. The total number of children in all the schools tested on the Digit-Symbol test was 992 and the number tested on the Symbol-Digit test was 1049. The sexes were fairly well divided, there being 514 boys and 478 girls on the Digit-Symbol test and 541 boys and 508 girls on the Symbol-Digit test.

Method of Tabulation of Results

After the tests had been given, each paper was scored in the following manner. The number of blanks filled in correctly was counted, and this value was divided by the time allowed for the test, five or eight minutes as the case might be. This gives the number of correct blanks filled in per minute and will be called the score. This method of scoring is used by Pyle. The papers were then arranged according to chronological age. The median, 75 percentile and 25 percentile scores were then tabulated. These values were obtained by arranging the papers of each age in order of merit. The paper standing midway between the lowest and highest paper represents the median score; the paper standing one quarter of the way from the highest paper represents the 25 percentile, and the paper three quarters of the way from the highest paper represents the 75 percentile. For example, by referring to Table 6 we find there are 95 pupils aged 12, 75 per cent of whom had a score of 8.6 or better. One half had a score of at least 14.0 (*i.e.,* the median), and 25 per cent had a score of 19.4 or better. The highest and lowest scores at each age were also noted, and the number of papers at each age that reached the average score for hearing boys and for hearing girls respectively, as given by Pyle, was also counted. The number reaching Pyle's average for each age has been expressed in per cent of the total number of deaf children at each age. A division of the sexes was then made, and these same values were found for the girls and for the boys separately. A third division between the congenital and adventitious cases was also made and here the median alone was found. In two of the schools a further division of children according to the method of instruction, whether predominately oral or manual, was made. Our tables and curves showing the difference between these two groups do not reflect in any way upon either of these two methods of instruction. From our results it would be obviously invalid to draw any conclusions as to the superiority or inferiority of either the oral or manual method. Nor would a comparison of schools using any one method exclusively allow us to make any deductions as to the

method employed in the school in quesetion. The tests are primarily tests of native ability, and the superiority of any particular school would undoubtedly be due to a better selection of pupils in that school. The results merely indicate the learning ability of the children on these two tests. It is customary in most combined schools where both oral and manual methods of instruction are used, to relegate the slower and duller pupils to the manual classes, and this fact is shown clearly by the results of the tests.

These three divisions, according to age, sex and cause of deafness were carried out for each of the three schools separately and then for all the three schools combined. We are, therefore, able to compare the scores for the deaf child according to age, sex, and cause of deafness in each of the three schools; and finally we have age norms on about 1,000 deaf children arranged according to age, sex and cause. In addition to this, a comparison was sought between the children who were partially deaf and those totally deaf. The comparisons were worked out for two of the schools only. Total or partial deafness was based on the teachers' estimate. It may be said that the curves show no radical difference between the two groups. The data is not given here since we believe that the comparison is unreliable. It is extremely difficult to estimate the amount of hearing possessed by a deaf child. There can be no doubt that the estimates of the amount of hearing must have differed greatly among the various teachers.

In addition to this method of compiling the data, we have attempted a more direct comparison between each deaf child and the average hearing child of the same age. Each individual child's score was compared to the age norms as given by Pyle and the age of the hearing child to which this score most closely agreed was noted. This we have called the Pyle age. It gives the deaf child's performance in terms of the chronological age of the hearing child. The difference between this value or Pyle age and the deaf child's age will give the number of years accelerated or retarded on the test for each individual child. This method was employed so that some measure of the amount of acceleration or retardation of the deaf child could be arrived at. The curves and tables of retardation given later are based upon this method.

They do not include deaf children below age ten. Those aged eight and nine were omitted because there are no norms for hearing children below eight, and therefore no valid estimate of retardation could be made if the score of the deaf child was below the score of an eight-year-old hearing child. The scores of most eight and nine-year-old deaf children were actually below the average score of the eight-year-old hearing child.

The Results

I. *The Digit-Symbol Test*

A. Comparison of the Three Schools Separately. We give, first, a comparison of the scores of the children in the three schools. Table I shows the results for all the children tested in each of the three schools, designated A, B and C. The classification on this table as on all the following ones is according to age. The horizontal divisions of the table show the number of children tested, the 75 percentile, the median, the 25 percentile, the percentage reaching Pyle's norm for boys and the percentage reaching Pyle's norm for girls. In each division the values for the three schools, A, B and C, are given. This arrangement of the tables is uniform throughout the work.

It will be noted that the number tested at most ages in each school is sufficiently large to give a fairly reliable median at each age. The quartiles and medians rise fairly uniformly from year to year in each school. The percentage of children reaching the boys' and girls' median at each age shows no uniformity. Evidently some age groups in some schools are much poorer than others in comparison to hearing children. A far greater number reach the median for hearing boys than for hearing girls. This is due to the fact that hearing girls have higher scores than hearing boys at every age. School C shows the highest percentage of children reaching the boys' and girls' median. The average is 32.8 per cent for the boys' median and 21.18 per cent for the girls'. School A comes next, and school B last. This is an indication of the relative position of the three schools with respect to the ability of the pupils on these tests.

A comparison of the medians of the three schools is seen best

from Graph 1. School C shows the highest median at all ages except nine and eighteen. School B shows the lowest median at all ages, except age seventeen. School A takes an intermediate position between the other two schools.

Table 2 shows the results for deaf boys. The medians and percentiles do not rise so uniformly, since we are dealing with much smaller numbers in each group. The same remarks apply to Table 3 showing the data for deaf girls. The relative position of the three schools remains about the same for the two sexes as in Table 1 for both sexes combined.

The comparison between the abilities of the boys and girls can be seen best from Graphs 2, 3 and 4, which compare the work of the boys and girls in the three separate schools. In all three graphs there is so much crossing and re-crossing of the curves as to indicate no constant and uniform sex difference on this test. In school B we note that the young girls (ages 9-11) are decidedly inferior to the boys of the same ages. The eleven-year-old girls are strikingly so. In school C we find that the 17 and 18-year-old girls are also much inferior to the boys of the same ages. Variations of this nature seem to be due to accidental causes. The number of children in any one age and sex group in any one school is relatively small, and the ability of any such group is liable to change from year to year owing to the composition of the group. On the whole, however, the younger girls in each school seem to be less efficient than the boys of the same age.

The comparison between the deaf boys of each school and the hearing boys as tested by Pyle is given in Graph 5. A similar comparison between the girls is shown in Graph 6. One striking feature about these two graphs is the fact that the curves for the deaf scarcely ever reach the curves for the hearing. The 16-year-old boys of school C surpass somewhat the hearing boys of that age. In the lower ages (8, 9 and 10) in both graphs, it is to be noted how great the discrepancy is between the performance of the deaf and the hearing children. Another interesting feature about the two graphs is the fact that the deaf boys approach the hearing boys more closely than the deaf girls approach the hearing girls. The deaf girls are not inferior to the deaf boys, as we saw

in the previous graphs, but they are further away from the hearing girls than the deaf boys are from the hearing boys, because the hearing girls do better than the hearing boys on this test. In comparing the three schools, we note that the boys of school C surpass the boys of the other two schools to a greater degree than the girls of school C surpass the girls of the other two schools.

Table 4 and Graphs 7, 8 and 9 give the comparison between the children congenitally and adventitiously deaf. No uniform and constant difference between these two groups is apparent either from the tables or the graphs. There seems to be a suggestion of the adventitious cases being inferior in the lower ages, but it must be borne in mind that there are generally fewer adventitious than congenital cases in the lower ages. We cannot conclude from the data that either of these groups shows a superiority over the other in learning ability.

Table 5 and Graphs 10 and 11 show the comparison between the oral and manual pupils in schools A and B. In school C no manual instruction is given, and therefore this comparison is impossible for that school. The inferiority of the manual pupils, as a whole, is apparent in both schools. At only one age (age 12, school A) do the manual pupils surpass the oral pupils. The difference between the two groups is by no means constant at every age in both schools. At some ages this difference is insignificant, whereas at others it is very great. The drop in the curve at age 18 in school B is not significant, as only three manual pupils are represented at that age. That the manual pupils should be inferior to the oral pupils is to be expected, since it is the general policy of combined schools to endeavor to teach all pupils by the oral method and to relegate to the manual classes only such pupils as fail to make progress with oral work. The fact, however, that we do find many manual pupils who are decidedly superior to oral pupils in this test of learning ability might raise the question whether there is not a type of pupil who, for some reason or another, cannot make progress under oral instruction and yet is by no means lacking in ability in other directions, where speech and lip reading are not required. The results may, of course, be

interpreted in another way, as meaning that the selection of the brighter pupils for oral instruction has not been carried out consistently. We would suggest that in making such classifications great help might be obtained from appropriate mental tests.

B. All Schools Combined. The combination of the results of all three schools is shown in Table 6, and the medians for each age are represented by the curves in Graph 12. The total number of children tested is 992, a number large enough to insure fairly reliable norms for each age. We believe that the medians from age 10 to age 18 may be regarded as fairly typical of the deaf child's learning ability. These medians would furnish reliable age norms for the comparison of the performances of other deaf children. The curve rises steadily from age 8 to the adult age group with one slight drop at age 11. This drop can be accounted for by the strikingly poor performance of the 11-year-old girls at school B. A larger number of 10- and 11-year-old children might smooth the curve at this point. The norm for adults, as we have called the pupils above age 18, cannot of course be taken as typical of the adult deaf in general. These so-called adults were all pupils of deaf schools, and it is reasonable to suppose that in general it is not the brightest group of deaf pupils who remain in school after the age of 18. In spite of this fact, it is interesting to note that their median score is 0.6 more than the score for the 18-year-olds. The line giving the highest scores shows that, at almost every age, a very high score is reached by some one child, and the line giving the lowest scores shows that in every age group there are cases of absolute inability to comprehend the test. The percentage reaching Pyle's medians for boys and for girls seems to show a slight tendency to increase in the upper ages, although this tendency is, by no means, uniform In the last two horizontal columns a comparison has been made between the median of the deaf child at each age and the median for the hearing child. For example, the deaf children of age twelve have a median score of 14.0 which corresponds to the median score of nine-year-old hearing children or a retardation of three years as a group. This retardation is shown in the last horizontal column, and will be discussed later, along with the other and better method of estimat-

ing retardation. The average amount of retardation estimated in this way is 3.75 years.

Tables 7 and 8 show the results for the two sexes, and Graph 13 gives a comparison of the medians at each age. There is a fairly constant increase from age to age with the boys, whereas with the girls we see considerable irregularities from year to year. The most noticeable drop in the median is at age 11. We have noted above the low scores made by eleven-year-old girls in all schools. There seems to be no obvious reason why this should have occurred. The 17 and 18-year-old girls are also inferior and drop below the 15 and 16-year-olds. The graph shows us the comparison between the boys and girls. In general, the boys seem to do slightly better than the girls, yet the difference is by no means great. The superiority of the boys is shown, however, by the comparison between the deaf and hearing of the same sex in Graphs 14 and 15. The curve for the deaf boys is much closer to the curve for the hearing boys than the curve for the deaf girls is to the curve for the hearing girls. What we have seen to be true for each school comes again fully into prominence when all the children are massed together. This same difference between the deaf and hearing is shown in the tables by the percentage of deaf reaching the median of the hearing. Of deaf boys 24.2 per cent reach the median for hearing boys, whereas only 10.3 per cent of deaf girls reach the median for hearing girls. Again, the average retardation as calculated in the last two lines of the tables is only 2.8 years for boys, but for girls it amounts to 4.5 years. Again, in eight of the twelve age groups the highest individual score reached by any one child belongs to a boy. The more precocious development of the hearing girl as contrasted with the hearing boy does not seem to occur with deaf girls.

The results for the congenital and adventitious cases are given in Table 9, and the comparison can be made in Graph 16. As in the case of the three schools taken separately, here again, with all the cases combined, we are unable to find any decided difference between these two groups. It is true that in the higher ages the adventitious cases seem to be slightly better than the congenital ones. This could be easily explained by the fact that in the

higher ages we have a certain number of children who have lost their hearing at a comparatively late period of life and who have had the advantage of hearing and speaking. The number of these cases is, probably, too small to affect the group. Again, the accident which deprived them of hearing may have also affected their mentality somewhat, so that as a group the adventitious are not superior in learning ability to the congenitally deaf, as we would expect on *a priori* grounds. We find in the results of these tests no justification for the prevalent opinion that the adventitiously deaf as a group are superior to the congenitally deaf as a group.

C. Retardation. The method of calculating the retardation of each pupil has already been explained under "Tabulation of Results." Graph 17 shows the number of individuals accelerated or retarded in each of the three schools and in all the schools combined. It will be noted that the modes for schoods A and C lie at two years' retardation and for school B at three years. The mode of the combined curve lies at two years, although the median falls within the three-year-retarded group. Table 10 gives the actual numbers retarded at each age for the Digit-Symbol test in the upper third of the table. Table 11 gives the numbers and percentages for the groups of so-called Bright, Normal, Backward and Dull children. We have designated Bright all those two or more years accelerated; Normal all those one year advanced to one year retarded; Backward all those two or three years retarded; and Dull all those four or more years retarded. This classification is more or less arbitrary and does not imply a mental diagnosis of the cases. In each school we find the largest percentage of pupils in the Dull group, *i.e.*, four or more years retarded, it being 47.1 per cent in school B; 40.5 per cent in school A; and 31 per cent in school C. School C shows, by far, the largest percentage of Bright pupils, *i.e.*, 16.5 per cent as compared to 2.6 and 3.1 in the other two schools. The percentage of children in the Normal and Backward groups of all three schools do not differ greatly. The general shape of the curve of retardation for all the three schools combined is slightly skewed to the right. This is what our percentages show, namely that the greater number of children lie below two years' retardation rather than above it.

The median falls in the three year group. This corresponds fairly well with the retardation of 3.7 found by the much rougher method described above, and tabulated on Table 6.

II. *The Symbol-Digit Test*

A. Comparison of the Three Schools Separately. Our discussion of the Symbol-Digit test may be made briefer, since in all essentials the results bear out our findings on the Digit-Symbol test. A study of the tables and curves will show this. Table 12 and Graph 18 show the results for all the pupils in the three schools separately. The relative position of the three schools is about the same as in the previous test. School C shows higher medians at all ages, except 17 and 18, than either of the other two schools. Schools A and B are much closer together on this test, and it would be difficult to say which is superior. The curves for these two schools cross each other repeatedly. The percentage of cases reaching the medians for hearing girls and boys is noticeably greater in school C than in the other two schools.

Tables 13 and 14 show the results for the boys and girls respectively, and Graphs 19, 20, and 21 show the comparison between the two sexes for each of the schools. As in the previous test, we note that there is no significant sex difference. Noticeable again is the very poor performance of the 11-year-old girls of school B, and the extremely good performance of the 17-year-old boys of the same school. Graphs 22 and 23 bring out the contrast between the deaf child and the hearing child. All the three curves for the boys are much closer to the hearing boys' curve than the three curves for the deaf girls are to the hearing girls' curve. This is the same tendency noticed on the other test. The same factor can be seen by a comparison of the percentages of deaf boys and girls who reach the average for the hearing boys and girls.

The results of the grouping into congenital and adventitious cases for the three schools appear in Table 15, and a comparison of the medians can be made from Graphs 24, 25 and 26 showing the performance of the two groups in schools A, B and C respectively. It can be plainly seen from these curves that again there is no striking difference between the two groups.

Table 16 and Graphs 27 and 28 show the results of the division of oral and manual pupils. Again, the manuals are much worse than the orals, and as in the other test this is very noticeble in School B and not quite so apparent in school A. It will be seen, however, from Table 16 that there are relatively fewer manual cases in each age group.

B. All Schools Combined. The results of all the deaf children on this test are given in Table 17. This represents over a thousand children, and we believe that the norms can be regarded as fairly representative of the ability of deaf children in general. Graph 29 shows the curve for the medians, and it will be seen that, with one exception, there is a steady rise from age to age. The drop at age 14 is only from a score of 24.5 at age 13 to a score of 23.3 at age 14, or a difference of 1.2. This is not very large. Reference to the tables for the two sexes will show that the drop is due to a relatively poorer performance of the fourteen-year-old boys. It is interesting to note that this drop at age 14 does not occur in the other test (see Graph 12), and conversely the drop at age 11 in Graph 12 does not occur here in this test. The only indication of the weakness of the eleven-year-olds on this test is the slighter increase in score at age 11, as compared with the immediately preceding and succeeding ages. The percentage of children reaching the boys' median is 4.5 greater than in the Digit-Symbol test. The amount of retardation as estimated on the table by a comparison of medians is 2.9 or somewhat less than in the previous test.

The scores for the boys and girls are given in Tables 18 and 19 and Graph 30 shows the relative ability of the two groups. The girls on the whole seem slightly inferior to the boys, but the difference is by no means great or constant at each age. In general, we must conclude that the two groups show about the same ability. The contrast between each of the groups and the hearing children can be seen in Graphs 31 and 32. The deaf boys are always much nearer the hearing boys than the deaf girls are near to the hearing girls. At one point the deaf boys' curve actually rises above the hearing boys' curve. The curves for the girls (Graph 32) are always very far apart. This same

difference is brought out by the percentages on Tables 18 and 19. Of the deaf boys 31.6 per cent reach the norm for hearing boys, whereas of the deaf girls only 9.6 per cent reach the corresponding norm for girls. This same phenomenon has been commented upon in the discussion of the Digit-Symbol test.

The comparison of the congenital and adventitious cases is seen on Table 20 and Graph 33. As in the other test, we find no radical difference between these two groups. There is again the suggestion that the younger children among the adventitious group are inferior to the younger congenitals, and conversely that the older among the adventitious do better than the older congenitals. The difference is, however, very slight, and it is doubtful whether any importance should be attached to it. The adventitious curve is much more regular than the congenital. There is a decided drop at age 14 on the congenital curve. The poor performance of the congenital 14 year olds is obviously the cause of the drop at age 14, that we have already commented upon in discussing the general curve for all the deaf on this test (Graph 29).

C. Retardation. The distribution of the children according to the number of years retarded or accelerated is shown in Graph 34, which gives the distribution for each school separately and for all schools combined. The modes for schools A and C lie at two years' retardation, and for school B at three years. The mode for the combined curve lies at two years. The median falls within the two year group, but is so close to the three year group that if we had drawn our curve to show half years it would have been at two and one half years and even then very close to the three-year-group. This approximates closely the average amount of retardation calculated roughly by the medians as shown in Table 17, where it was found to be 2.9 years. As in the previous test, we have in the combined curve, a curve which is slightly skewed to the right, meaning that there is a much larger number below the mode than above it. In Table 10 the actual numbers for each of the schools and for all the children are given in the second third of the table and the percentages for the four groups is shown in Table 11. In this

test there is a somewhat higher percentage of "bright" children (11.6 per cent as contrasted with 8.4 per cent in the Digit-Symbol test). Conversely, there is a somewhat lower percentage of "dull" children, 37.3 per cent as contrasted with 38.5 per cent in the Digit-Symbol Test. The percentages of the other two groups differ by about one point. All these differences are very slight. Indeed, it is remarkable how similar the percentages for the different groups in the two tests are. This serves to indicate the reliability of these tests.

III. *Both Tests Combined*

In order to verify the results found with each test separately, it was deemed wise to work out retardation statistics for the combination of the two tests. For this purpose each child's average score was taken and this average score compared to the averages of Pyle's norms for each age. In the case of Pyle's results the only figures available are the averages for each age. The combined average as computed by us is, therefore, the average of two averages, and not the average of all the individual children's averages for both tests. Graph 35 gives the curves for each school separately and for all the cases combined. As before, the mode lies at two years' retardation for schools A and C and at three years for school B. The mode for the combined curve lies at two, and the median falls within the three-year-retardation group. In the Digit-Symbol test the median was in the three year group; in the Symbol-Digit test it was in the two year group, but very near the three year group; in the two tests combined it lies within the three year group. We are, therefore, justified in saying that the average deaf child is about three years retarded in learning ability.

This amount of retardation may be slightly over-estimated in view of the fact that the norms for the older hearing children probably represent a more select group of children than is the case with the children educated at schools for the deaf. This is due to the fact that the norms for the higher ages of hearing children are obtained for the most part from High School pupils and College students, who are apt to be superior to the general population. However, it must be borne in mind that the deaf

child had a greater advantage in our tests owing to our method of procedure as we have noted above. The disadvantage to the deaf child was, probably, offset by his advantage in the method of procedure. For this reason, we feel our general result to be a correct estimate of the relative ability of the hearing and deaf child.

The actual numbers retarded or accelerated at each age are shown in the lower third of Table 10, and the percentages of the four groups in Table 11. A comparison of these figures and percentages with the retardation statistics for each test separately as given in Tables 10 and 11 will show the general similarity of the results. It is noticeable that in combining the two tests we get a slightly lower percentage of "bright" pupils. The general similarity of the figures, however, gives us confidence in the results of the two tests.

IV. *Correlations*

We assume that if these two tests really measure the learning ability possessed by an individual, any particular individual of a group will do relatively as well in one test as in the other. If A is first in the Digit-Symbol Test, what likelihood is there that he will also be first, or among the best, in the Symbol-Digit Test? If these tests depend upon pure chance and do not really measure an existent capacity, A is just as liable to be last as to be first in the second test. By correlational methods we can determine the degree of probability involved in the question asked above.

We have made the correlations in two ways. First we have correlated the results of the two tests by classes. Secondly, we have correlated the results by ages. Spearman's Correlation Foot-Rule or R method was used.[2] The formula is

$$R = 1 - \frac{6 \Sigma g}{n^2 - 1}$$

in which Σ g represents the sum of the gains made in the Symbol-Digit Test as contrasted with the Digit-Symbol Test, and n^2 is the number of pupils involved in the correlation, squared. This formula yields an index of correlation, R, that is not identical with the Pearson r. It is closely related, however,

[2] G. M. Whipple, Manual of Mental and Physical Tests, 1910. P. 34.

to r and has been converted into the Pearson r values by means of the standard table for conversion of R into r values.[3] In all cases where the P.E. (probable error) is given, we have used Table 5 in Whipple's Manual for the derivation of the same.

A. Correlation by Classes. Each one of the ninety classes was correlated separately. A sample of the method used is given below:

Pupil	D-S Test	S-D Test	Σg
A	1	1	
B	2	5	
C	3	2	1
D	4	3	1
E	5	6	
F	6	4	2
G	7	7	
			4

$$R = 1 - \frac{24}{48} = 1 - .50 = .50 . \qquad r = .71$$

From the above it is seen that pupil A was first in both tests, that G was last in both and that the others shifted their positions slightly. Pupil F gained 2 in the Symbol-Digit Test over his position in the Digit-Symbol Test. The correlation of this class is fairly high.

The average correlations of all the classes in each school along with the mean variations of the correlation coefficients are given below:

	Average r.	M.V.
School A. 26 classes		
Oral Classes	.55	.17
Manual Classes	.71	.12
All Classes	.61	.16
School B. 23 classes		
Oral Classes	.60	.21
Manual Classes	.72	.18
All Classes	.64	.21
School C. 41 classes		
Advanced Classes	.64	.15
Intermediate Classes	.68	.18
Primary Classes	.72	.16
All Classes	.68	.16

Average Pearson Coefficient of Correlation for the ninety classes in the three schools = .65.

[3] Whipple, op. cit. Table 6, p. 36.

These correlations are high enough to show that a pupil's standing in one test is in close functional correspondence with his standing in the other test. This is the more strongly emphasized by the fact that the average correlation for School A is .61. It will be remembered that the two tests were separated by an interval of about two months in School A. In spite of this interval and all the factors influencing the abilities of the various pupils, we still find that the average pupil keeps his relative position in the group fairly well.

The column headed M.V. shows the mean variations of the correlation coefficients for the different groups of classes. These figures show that the correlation coefficients do not fluctuate to any great extent. There are, of course, extreme cases in which the coefficient dropped to .20 on the one hand, and on the other rose to 1.00. The oral classes in Schools A and B seem to give lower correlations and larger mean variations than do the manual classes. We are not able to interpret this phenomenon at the present time. It is possible that this tendency may be indicative of the constitution of these class groups.

As School C represents but one classification according to method of instruction, we have given here the averages for the three departments of the school. It is interesting to note that as one goes from the Primary classes to the Advanced classes the correlation becomes lower. This may be merely a coincidence and we are inclined to believe that this is the case in view of the results obtained by the correlations of the various age groups.

B. Correlation by Ages. The same method was pursued here as in the previous section. All the pupils in a given age were ranked on each test in order of merit and the gains and losses of position noted. Spearman's R was then found and converted into Pearson's r value. The P.E. in each age was also derived as explained above. In all 960 pupils were tested on both tests.

Below are given the results of such correlation. In the first column are given the various ages, in the second the number of pupils tested on both tests, in the third the Spearman R, in the fourth the Pearson r and in the last the P.E.

Age	Number	R	r	P.E.
8	16	.68	.88	.0486
9	43	.55	.76	.0486
10	79	.56	.77	.0397
11	84	.49	.70	.0397
12	92	.58	.79	.0344
13	109	.61	.82	.0243
14	91	.56	.77	.0344
15	86	.51	.72	.0344
16	105	.64	.84	.0243
17	104	.60	.81	.0243
18	60	.58	.79	.0343
Ad.	91	.55	.76	.0344
	Average	.58	.78	.0351

The lowest correlation occurs at age 11 and the highest at age 8. There seems to be no constant difference in the correlations between the younger and the older ages. The variation from age to age is slight and follows no one direction. We conclude, therefore, that the tests classify the younger children as satisfactorily as they classify the older children. The average r for all ages is .78 with an average P.E. of .0351. This average age correlation is .13 higher than the average class correlation. This is to be expected in so far as the class correlations are all based on a relatively small number of pupils, while the age correlations are based on a much larger number, varying from 43 to 109. We mean by this that a small displacement in a small group is much more serious from the standpoint of a high correlation than the same displacement in a large group. The efficiency of these two tests is more fairly represented by the age correlations than by the class correlations, because of the larger number of pupils involved in them. The average r, .78, is a very high value, while the P.E. is very low. Whipple[4] states that a correlation is perfectly satisfactory, if it is three to five times as large as the probable error. Here we find the r to be twenty-two times the probable error, and this is evidence of the high degree of correlation between the two tests.

C. Correlations between the Class Grades and the Tests. In two of the schools, A and B, it was possible to work out cor-

[4] Whipple, op. cit. p. 32.

relations between the standing of the pupils in their class, as determined by the average examination mark for the year, and the standing of the pupils in the tests. The rank correlations for each test and school standing were computed for each class. Below are given the averages of the correlations and the average deviations for the oral classes, the manual classes and all the classes together.

School Grades and the Digit-Symbol Test.		
School A.	Average r	A.D.
Sixteen oral classes	.14	.22
Eight manual classes	.48	.12
Two High School classes	.17	.03
Total of 26 classes	.25	.17
School B.		
Sixteen oral classes	.18	.23
Six manual classes	-.05	.35
Total of 22 classes	.12	.26
School Grades and the Symbol-Digit Test.		
School A.		
Twenty-one oral classes	.29	.28
Nine manual classes	.46	.18
Two High School classes	.00	.14
Total of 32 classes	.32	.24
School B.		
Sixteen oral classes	.13	.18
Six manual classes	.10	.28
Total of 22 classes	.12	.21

It will be noted that all these correlations are very low. The large average deviations show the great fluctuations from class to class and indicate the presence of quite a number of negative correlations. In short the vast majority of classes show little correlation between the pupil's standing in the tests and the standing as determined by school grades. If the tests are testing intelligence, then the ordinary school examination is evidently testing something different. This raises a question too extensive to go into here. Our findings agree with those of other workers as cited and discussed by Stern.[5]

[5] Stern, William. The Psychological Methods of Testing Intelligence. Trs. by Whipple. Warwick and York, 1914. P. 61 et seq.

Conclusions

Two important features are to be noted in summing up the results of this investigation. The one is the general similarity of the results found in each of the three schools taken separately; and the other is the general similarity of the results for each of the twó tests. It seems safe to say that, since we find this general similarity in the three schools and in the two tests, the conclusions we have arrived at may be regarded as supported by sufficient evidence.

I. The deaf child is about three years behind the hearing child in learning ability, as tested by the rapidity and accuracy of forming associations between numbers and forms.

II. The deaf boy is equal in learning ability to the deaf girl, differing in this respect from the hearing boy who falls below the hearing girl.

III. The deaf boy approximates the hearing boy more closely than the deaf girl approximates the hearing girl in learning ability.

IV. The congenitally deaf and the adventitiously deaf are equal in learning ability.

In conclusion, we are of the opinion that something has been gained in establishing norms for these two tests. These norms for the deaf, as a whole, are found in Table 6 for the Digit-Symbol test and in Table 17 for the Symbol-Digit test. We believe that they form a reliable basis for comparing the work of any individual deaf child with the average deaf child of the same age. We wish emphatically to deny the possibility of an accurate mental diagnosis of any one child on the basis of these two tests, and yet a very poor performance on both of these tests might arouse a suspicion that could be verified by other mental tests. In regard to groups of deaf children we have faith that the results of a group compared with our norms will give a good indication of the general mental level of the group. In this sense, we believe that these two tests are admirable for a general survey of the mental level of a school. It will not do, however, for such work to be carried out by individuals indiscriminately.

A certain technique is necessary, and a strict conformity to the procedure as laid down by us is indispensable if results are to be at all comparable. We hold that most teachers are not fitted to give the tests from the mere fact that their attitude toward the child is naturally one of help and assistance. In some classes they would explain more than in others. This would invalidate the results. Strict adherence to a uniform mode of procedure is absolutely necessary. The results of tests conducted in such manner would undoubtedly prove useful in the classification of deaf children in practical school work.

TABLE 1. DIGIT-SYMBOL TEST. COMPARISON OF THE THREE SCHOOLS
ALL DEAF

Age		8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	A		7	27	35	33	35	23	30	52	42	26	41	351
	B		8	17	22	26	30	23	18	21	24	11	27	227
	C	15	29	34	27	36	51	45	37	40	42	30	27	413
75% ile	A		0	0	0	10.3	13.0	10.1	16.2	12.8	15.2	18.2	16.4	
	B		0	0.4	0	6.3	9.7	7.1	11.4	13.7	17.0	8.2	12.0	
	C	0	0	0	0	8.9	14.9	13.6	18.0	18.4	14.4	16.0	18.0	
Med.	A		4.3	9.1	10.8	13.2	16.8	17.0	19.6	21.1	21.4	25.6	21.6	
	B		3.2	6.3	1.6	13.0	13.6	13.8	16.8	20.0	22.8	17.8	20.4	
	C	0	3.7	9.5	10.6	18.1	18.8	20.2	22.1	25.0	23.8	24.8	24.8	
25% ile	A		9.3	13.2	13.0	15.2	20.2	20.8	23.6	23.8	26.4	29.6	29.0	
	B		15.6	12.2	9.6	18.1	18.6	20.8	21.0	23.6	26.4	21.0	25.6	Average
	C	1.5	11.4	13.8	16.9	22.1	23.7	25.4	26.4	29.6	29.6	30.4	30.0	(omitting age 9)
% reaching Boys' Med.	A		14	19	11	12	17	21	23	21	33	42	27	21.8
	B		25.0	11.7	9.1	15.4	3.3	21.5	11.0	19.0	41.0	9.0	18.5	16.0
	C	0	13.8	8.8	33.0	44.5	29.2	31.1	37.8	52.5	38.1	26.8	26.0	32.8
% reaching Girls' Med.	A		0	11	6	9	11	4	10	15	7	46	19	12.5
	B		25.0	5.8	4.5	3.9	0	0	0	9.5	8.3	9.0	0	3.1
	C	0	6.9	5.9	25.9	19.4	25.2	11.1	18.8	32.5	31.0	23.4	18.6	21.18

TABLE 2. DIGIT-SYMBOL TEST. COMPARISON OF THREE SCHOOLS

DEAF BOYS

Age		8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	A		2	17	21	22	18	8	16	29	21	11	21	184
	B		3	7	5	11	19	12	7	12	11	5	10	102
	C	8	18	11	14	22	35	23	19	22	24	17	13	226
75% ile	A			0	0	10.0	12.0	0	16.6	12.8	17.4	18.6	14.6	
	B		0	5.7	0	6.3	11.0	7.5	3.7	10.1	21.6	8.2	11.0	
	C	0	0	1.1	0.5	6.4	15.5	13.6	19.8	18.4	19.2	17.6	14.8	
Med.	A		8.5	10.0	12.2	12.1	14.1	13.7	17.6	20.5	22.0	25.8	20.0	
	B		9.7	8.4	8.1	12.0	15.0	13.0	16.9	19.1	24.0	18.4	15.6	
	C	0	7.7	7.5	15.1	16.2	19.5	19.7	22.0	26.4	26.0	26.0	24.2	
25% ile	A			13.6	14.1	14.3	19.6	19.2	23.0	23.0	27.0	29.6	30.0	
	B		15.6	12.2	8.5	16.6	18.7	21.2	21.4	26.6	28.2	24.6	25.0	
	C	5.4	12.1	15.1	20.7	20.0	25.0	26.0	26.4	33.0	31.2	32.8	28.8	
														Average (omitting age 9)
% reaching Boys' Med.	A		0	17	14	14	11	12	19	17	43	27	24	19.8
	B		33.0	0	0	0	0	25.0	14.3	33.3	54.0	20.0	20.0	16.6
	C	0	16.7	27.3	42.9	27.3	37.1	39.1	36.8	59.0	50.0	35.2	15.4	37.0

TABLE 3. DIGIT-SYMBOL TEST. COMPARISON OF THREE SCHOOLS

DEAF GIRLS

Age		8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	A		5	10	14	11	17	15	14	23	21	15	20	165
	B		5	10	17	15	11	11	11	9	13	6	17	125
	C	7	11	23	13	14	16	22	18	18	18	13	14	187
75% ile	A		0	0	0	13.1	14.1	13.1	15.0	12.0	12.3	18.2	17.1	
	B		0	0	0	7.9	2.4	0	12.3	13.6	15.8	14.0	14.4	
	C	1.0	0	0	0	10.7	6.8	10.1	12.9	13.2	0	16.0	21.6	
Med.	A		0	8.5	5.1	15.0	19.2	20.0	23.2	21.4	18.6	20.6	24.4	
	B		0	3.3	1.1	13.1	11.9	18.4	16.7	20.0	20.0	17.3	23.2	
	C	0	0	9.7	7.0	20.2	17.0	20.6	22.8	24.6	18.9	22.6	26.0	
25% ile	A		4.3	15.7	13.1	16.3	21.6	21.6	24.8	26.1	25.0	29.8	29.0	
	B		6.4	11.9	9.6	20.0	13.4	20.8	20.6	20.6	25.6	20.4	26.0	Average
	C	0	9.9	13.7	14.7	23.1	21.1	25.4	27.0	29.4	28.0	27.2	32.0	(omitting age 9)
% reaching Girls' Med.	A		0	10	7	9	18	7	14	17	5	40	20	14.7
	B		20.0	10.0	6.0	6.6	0	0	0	0	0	0	0	2.2
	C	0	0	0	15.4	35.7	12.5	13.6	27.8	33.3	22.2	7.7	28.3	19.64

TABLE 4. DIGIT-SYMBOL TEST. COMPARISON OF THREE SCHOOLS

ADVENTITIOUS CASES

Age		8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	A		3	12	19	19	22	13	17	28	28	17	26	204
	B		6	6	12	19	17	14	10	15	18	5	19	141
	C	2	5	20	18	23	30	22	20	21	26	18	12	217
Med.	A		0	10.2	11.5	13.1	16.0	15.1	19.6	20.8	21.7	25.6	24.4	
	B		3.2	3.3	2.5	13.1	12.0	13.5	12.9	20.6	23.2	17.8	20.4	
	C	0.5	0	9.8	11.8	17.9	20.0	20.4	23.6	26.2	22.6	24.8	24.1	

CONGENITAL CASES

Age		8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	A		3	16	16	14	13	10	13	23	12	9	14	143
	B		2	11	10	7	13	9	8	6	6	6	8	86
	C	12	24	12	9	13	21	23	17	19	16	12	14	192
Med.	A		7.7	4.1	5.1	13.8	19.0	19.2	22.0	21.1	18.5	25.0	20.6	
	B		4.8	9.9	1.5	12.0	15.0	13.8	17.2	15.5	17.5	18.0	22.2	
	C	0	6.5	9.3	10.2	18.6	18.6	17.7	21.0	24.8	24.3	24.6	25.1	

TABLE 5. DIGIT-SYMBOL TEST. COMPARISON OF TWO SCHOOLS

ORAL PUPILS

Age		8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	A		6	24	21	20	24	12	17	27	12	10	8	181
	B		7	15	18	22	27	16	9	13	16	8	15	166
Med.	A		6.0	9.2	10.8	13.0	19.4	20.0	22.0	23.0	22.4	25.6	23.6	
	B		6.4	8.4	5.5	13.1	13.8	14.7	20.9	20.6	23.2	21.4	25.6	

MANUAL PUPILS

Age		9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	A			14	13	11	11	13	24	29	12	17	144
	B	1	2	4	4	3	7	9	8	8	3	12	61
Med.	A			8.1	14.3	14.1	13.8	17.0	12.8	20.6	24.0	16.4	
	B	0	1.5	0	4.0	13.4	12.2	15.2	15.5	21.7	0.4	13.1	

TABLE 6. DIGIT-SYMBOL TEST. ALL SCHOOLS COMBINED

ALL DEAF

Age	8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	15	44	79	84	95	116	91	85	113	108	67	95	992
75% ile	0	0	0	0	8.6	12.0	10.1	15.7	14.0	16.6	17.4	15.2	
Med.	0	3.6	8.9	7.5	14.0	17.5	18.4	20.9	21.1	22.1	22.6	23.2	
25% ile	2.8	9.7	13.1	13.9	19.4	20.6	21.9	24.8	26.4	27.0	29.0	28.9	
Range High	8.2	21.4	19.7	26.3	30.0	33.0	36.6	36.4	46.0	36.2	47.3	38.2	
Range Low	0	0	0	0	0	0	0	0	0	0	0	0	Average
% reaching Boys' Med.	0	13.6	10.1	15.5	25.1	16.4	20.9	25.9	31.8	29.6	23.9	21.0	21.7
% reaching Girls' Med.	0	2.3	5.1	11.9	10.5	13.8	5.5	11.8	18.6	15.7	23.9	11.6	12.2
Pyle Age of Med.	—8	—8	—8	—8	9	11	11.5	12	12.5	12.5	12.5	13	Av. Retn.
Years Retarded	?	?	?	?	3	2	2.5	3	3.5	4.5	5.5	6	3.75

TABLE 7. DIGIT-SYMBOL TEST. ALL SCHOOLS COMBINED

DEAF BOYS

Age	8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	7	24	36	38	56	72	43	42	63	56	33	44	514
75% ile	0	0	1.1	0.2	8.2	13.0	10.0	16.6	14.4	20.0	18.2	13.0	
Med.	0	7.7	9.2	11.3	13.2	18.3	16.2	20.8	21.1	24.1	25.6	20.8	
25 % ile	5.4	11.4	13.2	15.2	17.4	21.0	23.0	24.4	26.9	28.2	30.2	28.4	
Range { High	8.2	15.6	19.7	26.3	26.0	33.0	36.6	36.4	46.0	35.2	47.3	36.6	
Range { Low	0	0	0	0	0	0	0	0	0	9.5	0	0	
% reaching Boys' Med.	0	16.7	11.1	21.0	16.1	20.8	25.6	23.8	34.9	39.3	30.2	20.4	24.2
Pyle Age of Med.	—8	—8	—8	8.5	9.5	11.5	11	12.5	12.5	15	16.5	12.5	Av. Retn.
Years Retarded	?	?	?	2.5	2.5	1.5	3	2.5	3.5	2	1.5	6.5	2.8

TABLE 8. DIGIT-SYMBOL TEST. ALL SCHOOLS COMBINED

DEAF GIRLS

Age	8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	8	20	43	46	39	44	48	43	50	52	34	51	478
75 % ile	0	0	0	0	11.0	10.0	10.1	13.2	13.4	13.1	16.5	18.0	
Med.	0	0	8.5	4.0	15.2	15.8	18.9	21.8	21.2	18.8	20.5	24.0	
25% ile	4.6	7.9	13.3	13.1	20.8	20.6	21.9	24.9	26.0	25.0	27.2	29.1	
Range { High	5.0	21.4	19.3	24.0	30.0	29.6	32.0	31.1	34.0	36.2	35.6	38.2	
Range { Low	0	0	0	0	0	0	0	0	0	0	0	0	
% reaching Girls' Med.	0	5.0	4.6	8.7	15.4	6.8	4.2	13.9	16.0	7.7	17.6	13.7	10.3
Pyle Age of Med.	—8	—8	—8	—8	9	9	11	11.5	11.5	11	11.5	13.5	Av. Retn.
Years Retarded	?	?	?	?	3	4	3	3.5	4.5	6	6.5	5.5	4.5

TABLE 9. DIGIT-SYMBOL TEST. ALL SCHOOLS COMBINED

Adventitious Cases

Age	8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	2	14	38	49	61	69	50	47	64	72	41	57	564
Med.	0	0	9.1	8.1	14.0	17.9	18.5	21.0	21.0	22.3	24.0	23.6	

Congenital Cases

Age	8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	11	26	39	35	34	47	41	38	48	34	26	36	415
Med.	0	7.7	8.9	5.1	14.0	16.6	18.4	20.5	21.4	20.0	20.4	21.6	

TABLE 10. NUMBER ACCELERATED OR RETARDED

Years Accelerated or Retarded		+6	+5	+4	+3	+2	+1	0	—1	—2	—3	—4	—5	—6	—7	—8	—9	—10	—11	—12	—13+
Digit-Symbol—																					
No. at each Year	A	0	0	4	3	5	17	34	31	63	51	35	26	20	16	19	8	10	3	2	3
	B	0	0	0	0	6	9	16	24	25	41	24	25	18	13	13	4	5	2	1	3
	C	7	5	7	16	26	25	39	35	56	37	30	24	17	12	14	7	5	2	1	1
All Schools		7	5	11	19	37	51	89	90	144	129	89	75	55	41	46	19	20	7	4	7
Symbol-Digit—																					
No. at each Year	A	0	1	3	10	12	19	35	32	65	53	47	27	31	13	13	18	5	6	0	0
	B	0	1	6	4	7	12	14	17	30	34	28	15	17	14	8	8	2	4	0	0
	C	7	10	10	14	28	21	38	40	52	35	28	24	21	15	8	7	1	3	0	0
All Schools		7	12	19	28	47	52	87	89	147	122	103	66	69	42	29	33	8	13	0	0
Average of Both Tests—																					
No. at each Year	A	0	0	2	6	7	12	25	34	56	54	39	23	26	17	16	10	3	5	0	0
	B	0	0	1	2	4	10	21	11	30	35	31	23	20	10	8	5	4	6	0	0
	C	4	8	5	17	19	25	44	42	47	39	27	26	24	15	9	6	2	3	0	0
All Schools		4	8	8	25	30	47	90	87	133	128	97	72	70	42	33	21	9	14	0	0

TABLE 11. ACCELERATION AND RETARDATION BY GROUPS

	School A		School B		School C		All Schools	
	No.	%	No.	%	No.	%	No.	%
Digit-Symbol								
Bright	12	3.1	6	2.6	61	16.5	79	8.4
Normal	82	23.4	49	21.2	99	27.0	230	24.3
Backward	114	32.6	66	28.8	93	25.0	273	28.9
Dull	142	40.5	108	47.1	113	31.0	363	38.5
Total	350	100.6	229	99.7	366	99.5	945	100.1
Symbol-Digit								
Bright	26	6.6	18	8.1	69	19.0	113	11.6
Normal	86	22.0	43	19.5	99	27.0	228	23.4
Backward	118	30.0	64	28.9	87	24.0	269	27.6
Dull	160	41.0	96	43.4	107	29.0	363	37.3
Total	390	99.6	221	99.9	362	99.0	973	99.9
Average of Both Tests								
Bright	15	4.5	7	3.2	53	14.7	75	8.2
Normal	71	21.2	42	19.0	111	30.5	224	24.4
Backward	110	32.8	65	29.4	86	23.7	261	28.4
Dull	139	41.5	107	48.4	112	30.9	358	39.0
Total	335	100.0	221	100.0	362	99.8	918	100.0

TABLE 12. SYMBOL-DIGIT TEST. COMPARISON OF THREE SCHOOLS

ALL DEAF

Age		8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	A	9	17	38	44	39	33	34	40	44	40	32	46	416
	B	1	8	17	22	27	28	24	17	22	24	11	27	228
	C	15	28	35	26	37	48	45	38	37	42	29	25	405
75% ile	A	0	0.3	0	5.7	6.2	14.2	12.9	15.0	16.0	14.0	20.4	14.6	
	B		0	3.4	0	8.2	11.5	8.9	18.4	13.9	17.4	13.2	18.0	
	C	0	0	0	7.7	13.0	17.2	14.7	17.5	19.6	19.2	19.2	20.4	
Med.	A	0	4.3	7.8	11.2	12.8	19.4	17.4	20.4	22.2	21.0	24.7	20.8	
	B	(9.0)	4.0	11.0	7.0	15.2	17.2	17.4	22.6	17.3	24.5	21.4	23.4	
	C	0	9.1	12.1	13.8	17.8	22.7	20.5	24.0	25.6	24.1	24.4	25.6	
25% ile	A	6.1	9.0	13.0	16.2	18.4	23.0	21.2	25.8	27.6	28.0	31.8	28.2	
	B		14.5	16.1	13.6	22.2	23.0	23.4	25.8	24.0	31.2	24.6	26.6	
	C	6.1	12.4	16.8	18.6	24.8	28.4	26.7	28.2	29.2	30.1	32.2	31.7	
														Average
% reaching Boys' Med.	A	0	11.7	13.1	18.1	20.5	30.3	11.7	25.0	22.7	25.0	28.1	17.3	20.2
	B		25.0	17.6	13.6	37.0	35.7	25.0	23.5	9.0	37.5	9.0	7.4	22.8
	C	6.6	17.8	25.7	30.9	48.6	56.2	35.6	39.5	40.5	35.7	34.5	20.0	35.6
% reaching Girls' Med.	A	0	0	5.2	11.3	5.1	9.1	2.9	12.5	15.9	5.0	15.6	17.3	9.6
	B		12.5	11.7	4.5	18.5	14.2	16.6	11.7	9.0	25.0	0	7.4	12.7
	C	6.6	7.1	11.4	23.0	29.7	33.3	22.2	18.4	21.6	26.2	17.2	20.0	21.2

TABLE 13. SYMBOL-DIGIT TEST. COMPARISON OF THREE SCHOOLS

DEAF BOYS

Age		8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	A	5	7	23	27	24	18	14	20	25	21	14	24	222
	B		3	7	5	12	17	13	6	13	11	5	10	102
	C	7	18	11	13	23	32	23	20	19	24	16	11	217
75% ile	A	0	4.1	0	5.3	6.1	15.3	11.0	18.0	17.6	16.0	20.7	15.4	
	B			11.0	4.5	8.2	14.7	7.6	18.4	11.3	23.4	5.9	9.4	
	C	0	0	6.6	8.8	12.5	18.6	18.7	18.7	20.6	21.8	18.8	20.0	
Med.	A	0	4.3	9.8	11.2	13.8	19.3	16.3	22.0	23.4	21.0	26.2	20.2	
	B		8.0	12.4	9.9	12.7	18.8	15.8	22.8	17.0	30.0	21.4	18.2	
	C	6.1	9.6	10.8	14.3	17.3	24.4	21.6	24.1	25.6	28.8	26.6	25.4	
25% ile	A	5.0	5.6	13.4	17.2	19.6	22.2	20.0	27.0	29.0	28.0	35.0	24.4	
	B			22.9	15.6	22.2	24.1	19.0	30.2	24.4	38.0	24.6	34.0	
	C	7.0	13.6	20.0	19.3	23.1	29.0	26.7	31.6	33.0	37.2	33.0	34.3	Average
% reaching Boys' Med.	A	0	14.3	13.0	18.5	25.0	27.7	14.3	30.0	24.0	23.8	35.7	16.6	21.6
	B		33.3	28.5	20.0	33.3	47.0	15.4	33.3	7.7	54.4	20.0	20.0	29.4
	C	14.3	27.7	27.2	38.4	43.4	65.6	30.4	45.0	47.3	50.0	37.5	27.2	41.9

TABLE 14. SYMBOL-DIGIT TEST. COMPARISON OF THREE SCHOOLS

DEAF GIRLS

Age		8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	A	4	10	15	17	15	15	20	20	19	19	18	22	194
	B	0	5	10	17	15	11	11	11	9	13	6	17	125
	C	8	10	24	13	14	16	22	18	18	18	13	14	188
75% ile	A	0	0	0	8.2	6.8	12.2	13.2	12.8	12.1	12.6	19.6	13.6	
	B		0	2.3	0	7.5	8.8	16.6	19.6	14.8	14.4	16.6	19.4	
	C	0	0	0	2.0	13.3	8.7	14.7	15.4	14.2	13.5	18.0	22.2	
Med.	A	2.5	5.8	4.6	11.2	11.7	19.4	19.6	18.3	20.4	20.0	22.0	24.6	
	B		0	6.6	5.2	16.9	15.5	20.7	22.6	17.6	17.6	19.8	24.6	
	C	0	1.5	11.5	13.1	19.9	17.9	17.1	22.8	25.5	20.9	22.2	25.8	
25% ile	A	6.8	9.7	10.2	12.9	18.0	23.0	21.6	25.4	27.3	28.6	32.0	32.4	
	B		11.9	14.5	13.6	22.2	20.2	27.8	24.8	24.0	30.2	24.6	26.6	
	C	1.7	12.4	16.8	19.5	27.5	24.4	26.4	27.2	29.2	27.2	30.8	31.7	
														Average
% reaching Girls' Med.	A	0	0	6.7	11.8	6.7	6.7	0	15.0	15.8	0	11.1	18.2	8.8
	B		20.0	0	5.9	20.0	9.0	27.2	0	11.1	7.7	0	0	8.8
	C	0	0	8.3	23.1	35.8	18.7	18.2	5.6	11.1	5.6	7.7	14.3	12.8

TABLE 15. SYMBOL-DIGIT TEST. COMPARISON OF THREE SCHOOLS

Adventitious Cases

Age		8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	A	4	8	15	21	22	22	17	24	19	28	21	32	233
	B	0	6	6	11	20	15	14	10	16	18	5	18	139
	C	2	5	20	17	23	29	23	20	19	27	17	11	213
Med.	A	0	3.3	9.8	12.2	10.7	19.3	20.0	20.5	21.8	21.0	24.6	24.0	
	B		5.9	12.7	5.2	16.6	16.0	17.5	20.0	19.4	26.3	21.6	22.5	
	C	3.3	1.7	11.0	14.3	19.5	20.4	20.6	23.3	26.4	24.2	25.0	27.0	

Congenital Cases

Age		8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	A	5	8	22	22	16	11	16	15	24	10	11	14	174
	B	0	2	11	11	7	13	10	7	6	6	6	9	88
	C	11	20	13	9	14	19	22	18	18	15	12	14	185
Med.	A	5.0	5.0	7.4	10.6	16.9	20.4	16.7	18.8	23.4	20.9	25.4	19.0	
	B		4.0	9.6	7.6	10.5	17.8	17.2	24.4	17.3	20.8	19.7	26.6	
	C	0	10.7	14.5	11.1	17.0	24.4	19.4	24.1	25.5	27.2	24.0	24.1	

TABLE 16. SYMBOL-DIGIT TEST. COMPARISON OF THREE SCHOOLS

Oral Pupils

Age		8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	A	9	13	33	31	23	23	24	22	21	15	13	9	236
	B	1	7	15	18	23	26	16	9	13	16	8	15	167
Med.	A	0	4.5	8.0	11.4	7.8	19.6	19.8	22.2	23.4	27.0	25.0	25.4	
	B	9.0	8.0	11.0	9.1	16.3	16.5	17.7	24.4	21.9	27.0	21.6	26.2	

Manual Pupils

Age		8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	A	0	4	4	13	16	10	10	18	22	25	14	20	156
	B	0	1	2	4	4	2	8	8	9	8	3	12	61
Med.	A		2.3	4.9	9.5	18.4	16.8	12.0	18.1	21.1	20.2	22.0	18.2	
	B			6.3	0	3.6	23.2	17.5	20.5	16.8	22.3	11.8	17.7	

TABLE 17. SYMBOL-DIGIT TEST. ALL SCHOOLS COMBINED

ALL DEAF

Age	8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	25	53	90	92	103	109	103	95	103	106	72	98	1049
75% ile	0	0	0	5.2	8.0	14.4	13.1	16.8	16.7	17.0	19.2	17.7	
Med.	0	5.0	9.7	11.2	16.0	19.6	18.4	21.8	22.4	23.0	23.7	23.5	
25% ile	6.3	12.1	15.1	16.2	22.1	24.5	23.3	26.9	28.8	29.6	29.7	28.5	
Range High	11.2	19.4	24.6	28.4	34.6	38.2	37.9	39.8	46.8	44.0	46.8	46.2	
Range Low	0	0	0	0	0	0	0	0	0	0	0	0	Average
% reaching Boys' Med.	4	17.0	18.8	19.6	31.0	43.1	24.2	30.3	26.2	32.1	27.8	15.3	26.2
% reaching Girls' Med.	4	5.7	8.9	12.0	8.7	21.1	13.6	14.7	16.5	17.9	12.5	15.3	13.7
Pyle Age of Med.	—8	—8	—8	8.5	10	12	11.5	13.5	13.5	14	14	14	Av. Retn.
Years Retarded	?	?	?	2.5	2	3	2.5	1.5	2.5	3	4	5	2.9

TABLE 18. SYMBOL-DIGIT TEST. ALL SCHOOLS COMBINED

DEAF BOYS

Age	8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	12	28	41	45	59	67	50	46	57	56	35	45	541
75% ile	0	0.1	3.5	6.3	8.5	15.7	11.0	18.3	17.1	20.4	20.8	14.5	
Med.	4.4	5.7	10.8	11.4	15.2	21.4	18.9	22.7	23.4	26.1	25.4	21.2	
25% ile	6.7	13.2	14.1	17.6	21.8	25.7	23.2	29.4	28.9	33.4	32.0	29.2	
Range High	11.2	19.4	24.6	25.6	31.2	38.2	37.9	39.8	46.8	44.0	46.8	46.2	
Range Low	0	0	0	0	0	0	0	0	0	0	0	0	Average
% reaching Boys' Med.	8.3	25.0	19.5	24.4	33.9	50.8	26.0	36.7	28.1	41.1	34.3	20.0	31.6
Pyle Age of Med.	—8	—8	8	8.5	9.5	13.5	11.5	13.5	14	15.5	15	13.5	Av. Retn.
Years Retarded	?	?	2	2.5	2.5	+0.5	2.5	1.5	2	1.5	3	5.5	2.25

TABLE 19. SYMBOL-DIGIT TEST. ALL SCHOOLS COMBINED

DEAF GIRLS

Age	8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	13	25	49	47	44	42	53	49	46	50	37	53	508
75% ile	0	0	0	1.5	7.6	10.1	14.1	13.8	14.5	14.2	18.3	18.3	
Med.	0	2.0	7.5	10.0	16.9	17.5	18.4	20.6	22.0	19.8	21.6	24.8	
25% ile	6.2	11.8	15.8	15.0	22.8	22.3	24.5	25.7	27.9	27.1	26.6	29.7	
Range { High	9.0	18.6	23.0	28.4	34.6	32.8	32.2	34.8	39.4	39.0	39.6	40.2	
Range { Low	0	0	0	0	0	0	0	0	0	0	0	0	
													Average
% reaching Girls' Med.	0	4.0	2.4	10.6	22.7	11.8	13.2	6.1	13.6	4.0	8.1	11.3	9.6
Pyle Age of Med.	—8	—8	—8	8	9	9.5	9.5	11	11.5	11	11.5	12.5	
													Av. Retn.
Years Retarded	?	?	?	3	3	3.5	4.5	4	4.5	6	6.5	6.5	4.6

TABLE 20. SYMBOL-DIGIT TEST. ALL SCHOOLS COMBINED

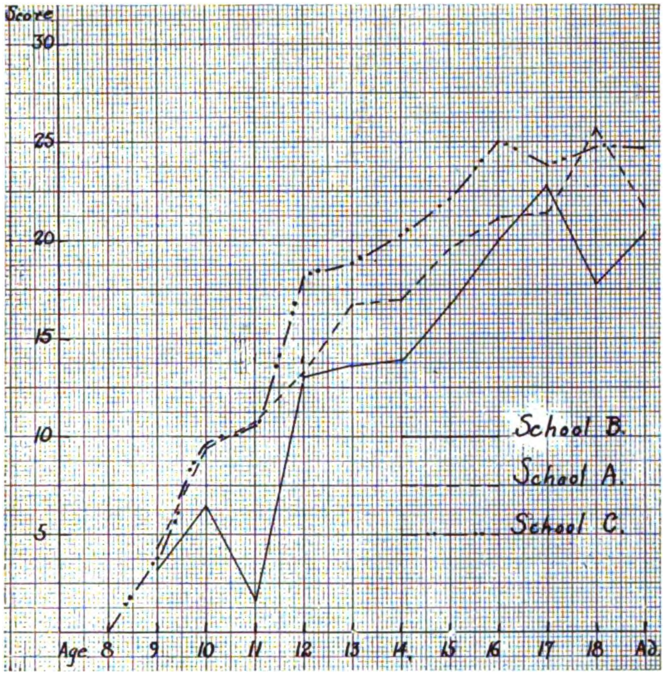
ADVENTITIOUS CASES

Age	8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	6	19	41	49	64	66	54	54	54	73	43	61	584
Med.	0	2.3	11.2	12.2	15.4	19.2	19.6	21.0	22.0	23.6	24.6	24.4	

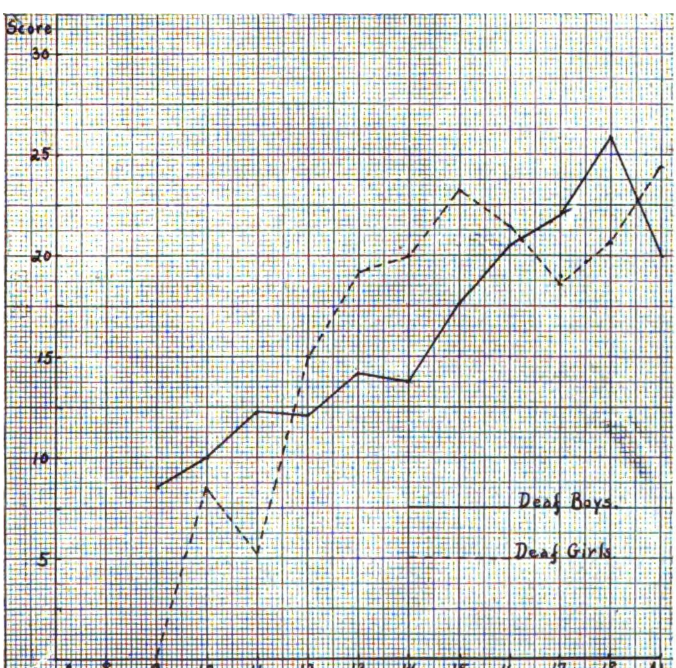
CONGENITAL CASES

Age	8	9	10	11	12	13	14	15	16	17	18	Ad.	Total
No.	17	30	46	42	38	43	48	40	48	31	29	37	449
Med.	1.7	7.2	8.9	10.8	16.9	21.4	17.2	22.7	23.2	23.4	23.6	23.0	

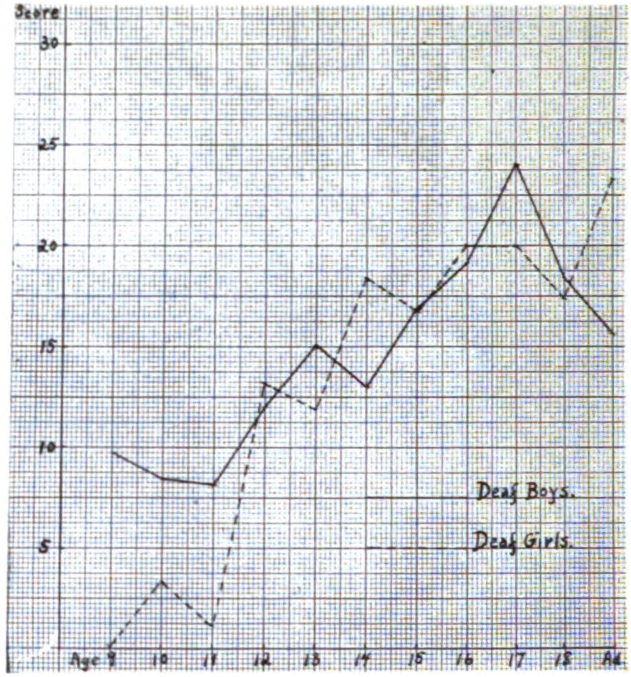
Graph 1. Digit-Symbol Test. Comparison of All Deaf in Three Schools.



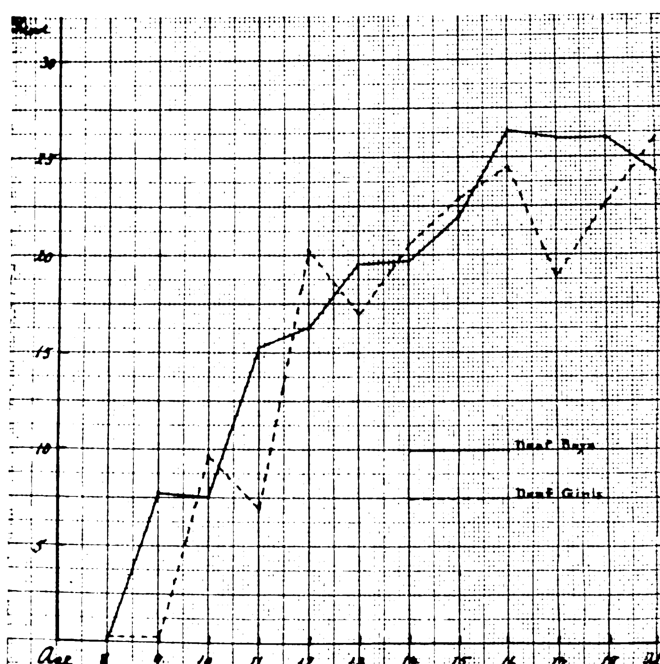
Graph 2. Digit-Symbol Test. Comparison of Boys and Girls. School A.



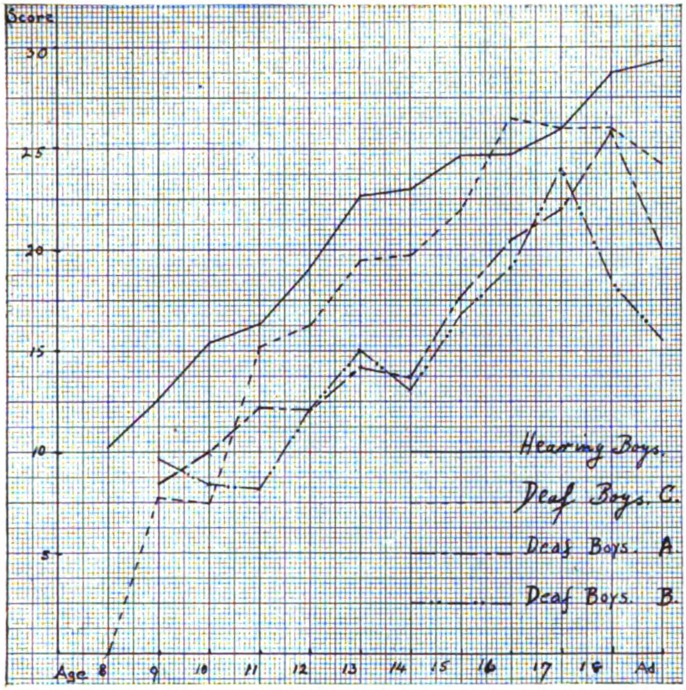
Graph 3. Digit-Symbol Test. Comparison of Boys and Girls. School B.



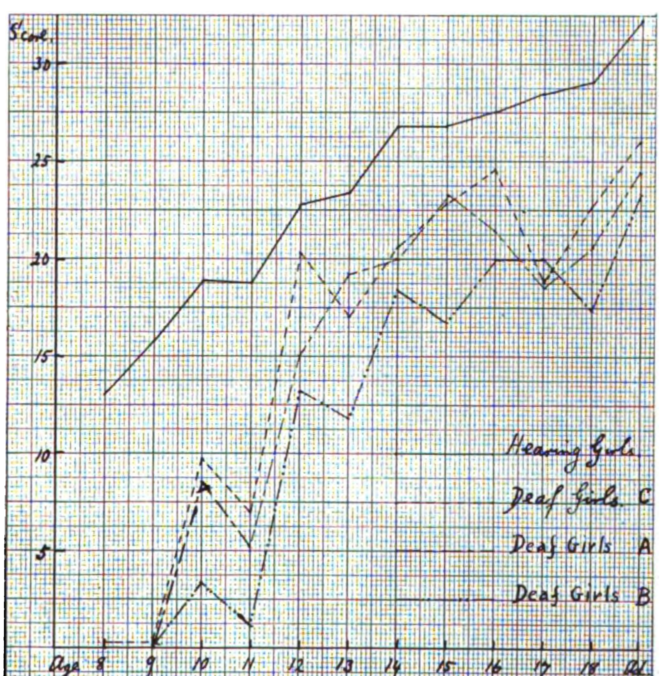
Graph 4. Digit-Symbol Test. Comparison of Boys and Girls. School C.



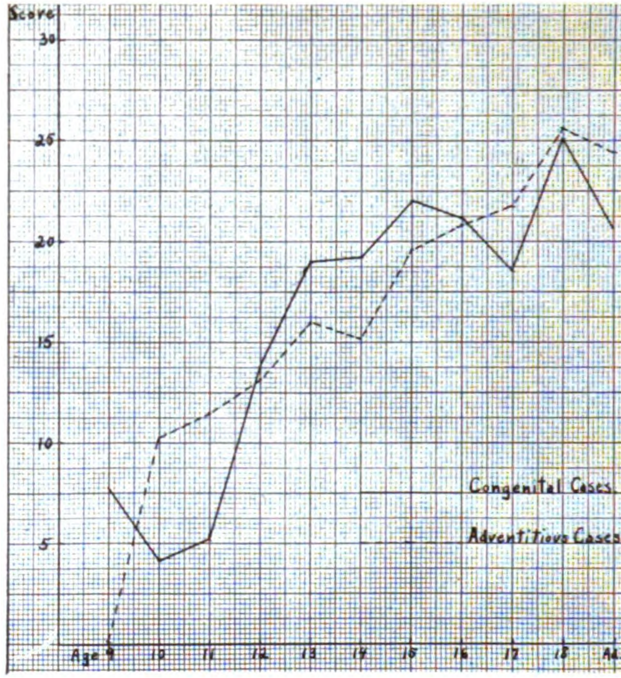
Graph 5. Digit-Symbol. Comparison of Hearing Boys and Deaf Boys.



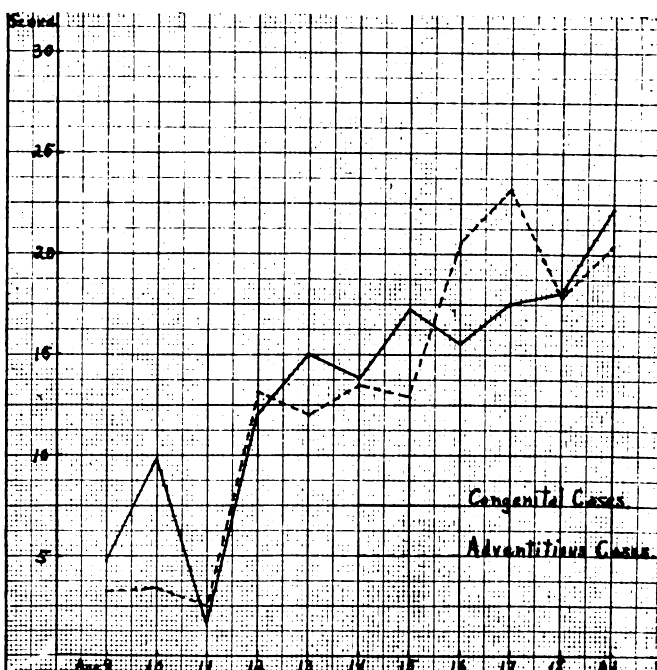
Graph 6. Digit-Symbol Test. Comparison of Hearing Girls and Deaf Girls.



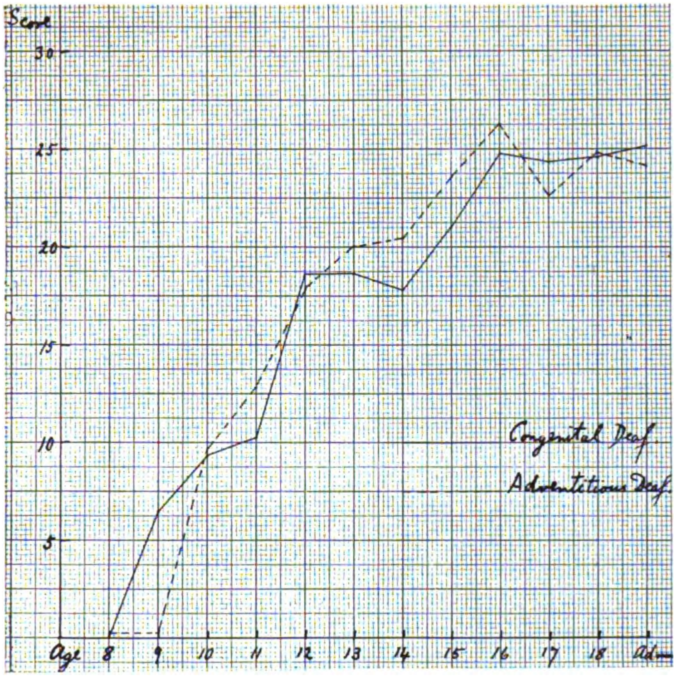
Graph 7. Digit-Symbol Test. Comparison of Congenital and Adventitious Cases. School A.



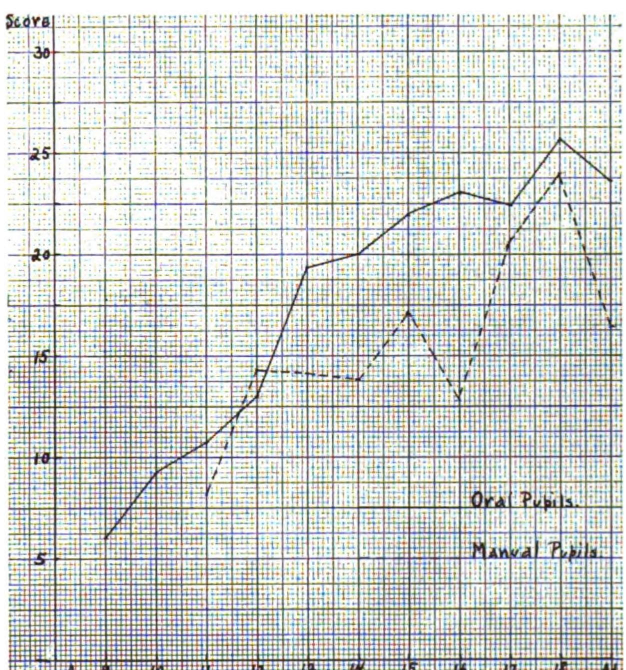
Graph 8. Digit-Symbol Test. Comparison of Congenital and Adventitious Cases. School B.



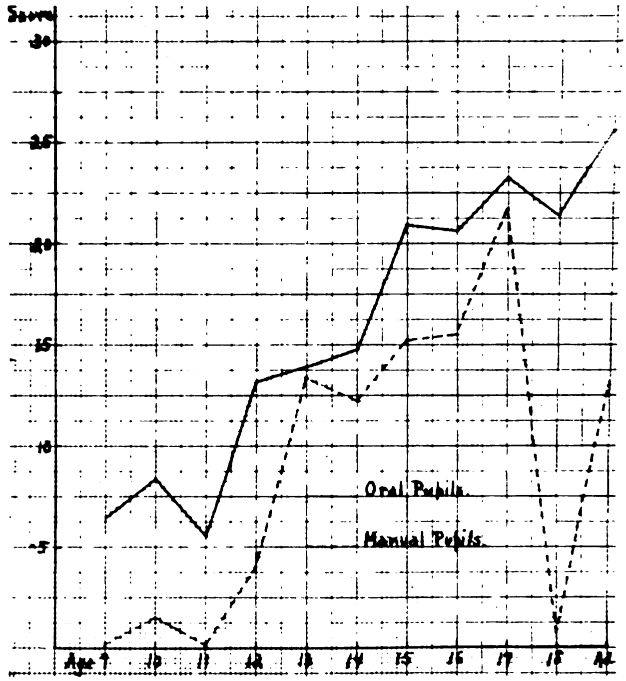
GRAPH 9. Digit-Symbol Test. Comparison of Congenital and Adventitious Cases. School C.



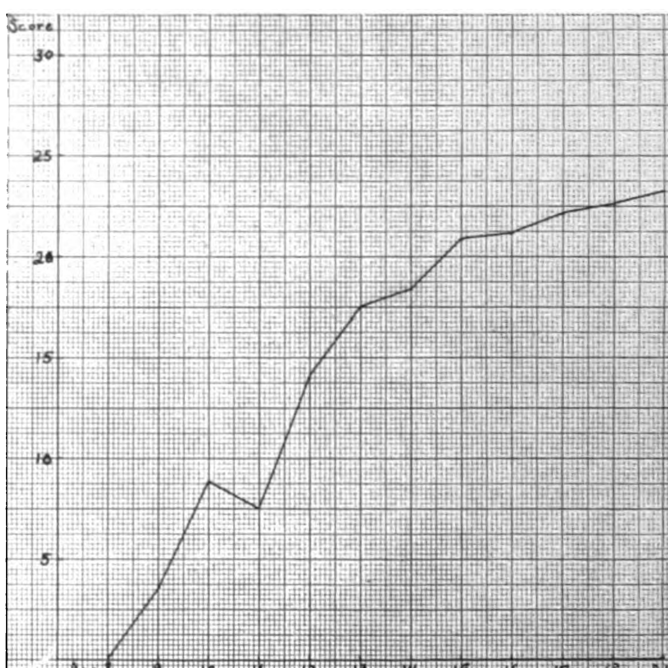
GRAPH. 10. Digit-Symbol Test. Comparison of Oral and Manual Pupils. School A.



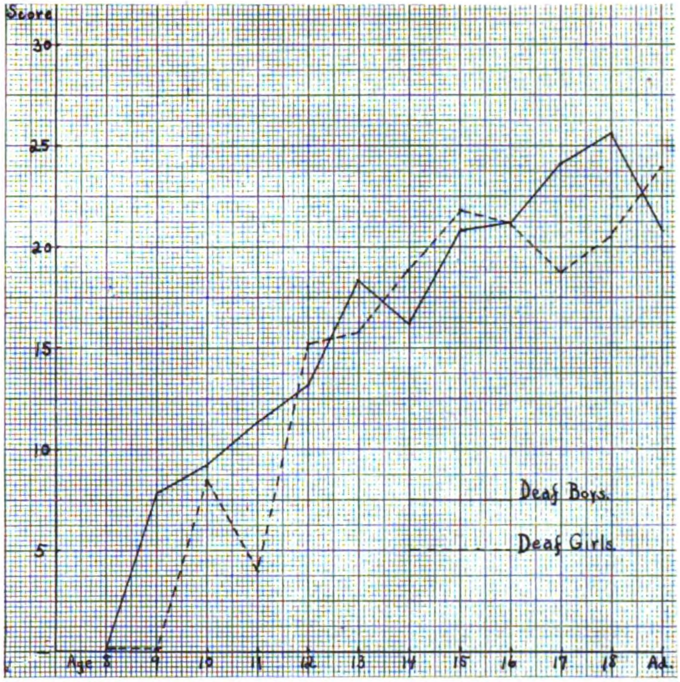
Graph 11. Digit-Symbol Test. Comparison of Oral and Manual Pupils. School B.



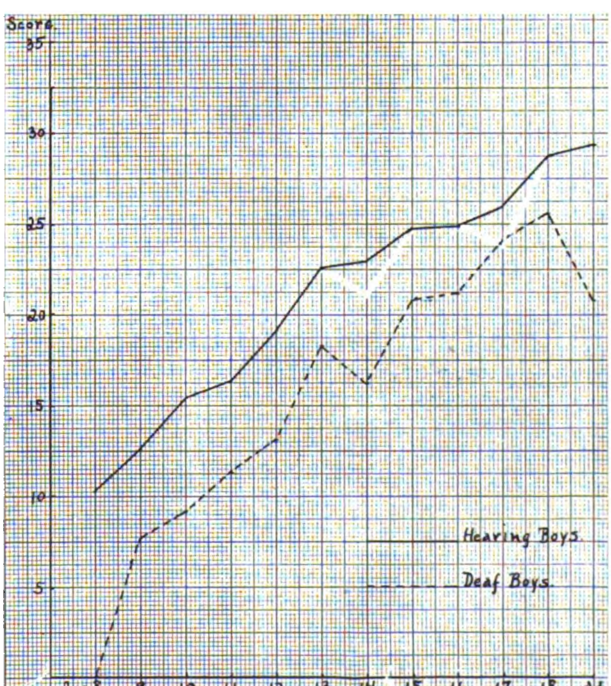
Graph. 12. Digit-Symbol Test. Age Norms for All the Deaf.



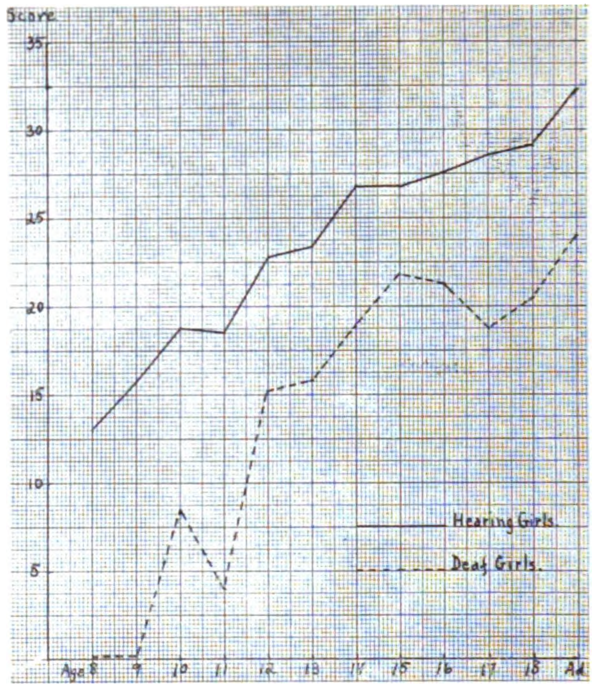
Graph 13. Digit-Symbol Test. Comparison of Boys and Girls of All Schools.



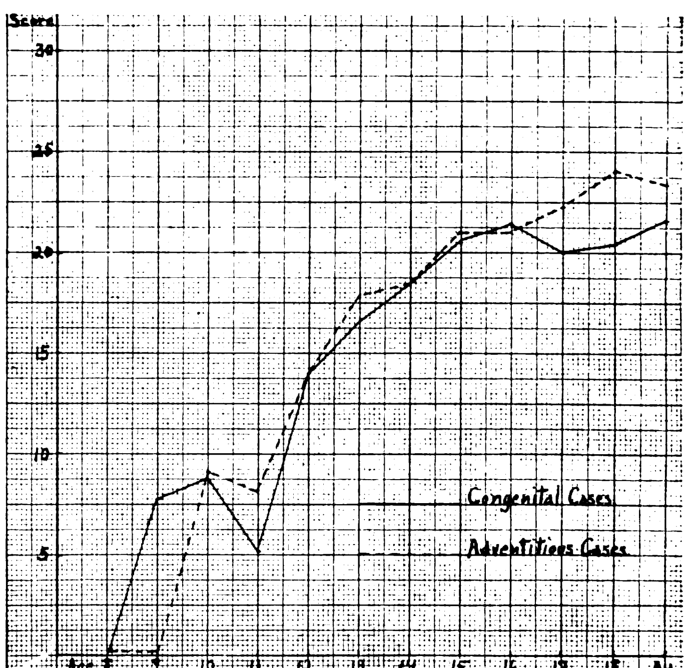
Graph 14. Digit-Symbol Test. Comparison of Hearing Boys and Deaf Boys of All Schools.



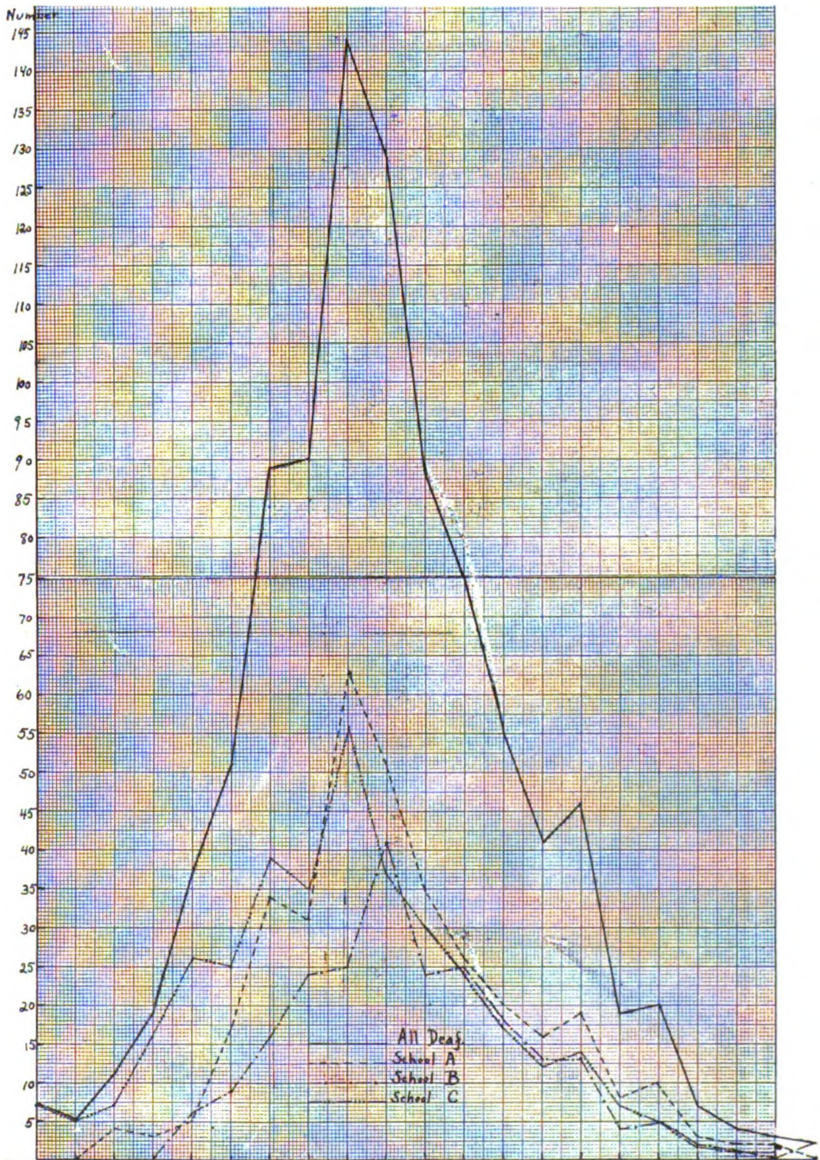
GRAPH 15. Digit-Symbol Test. Comparison of Hearing Girls and Deaf Girls of All Schools.



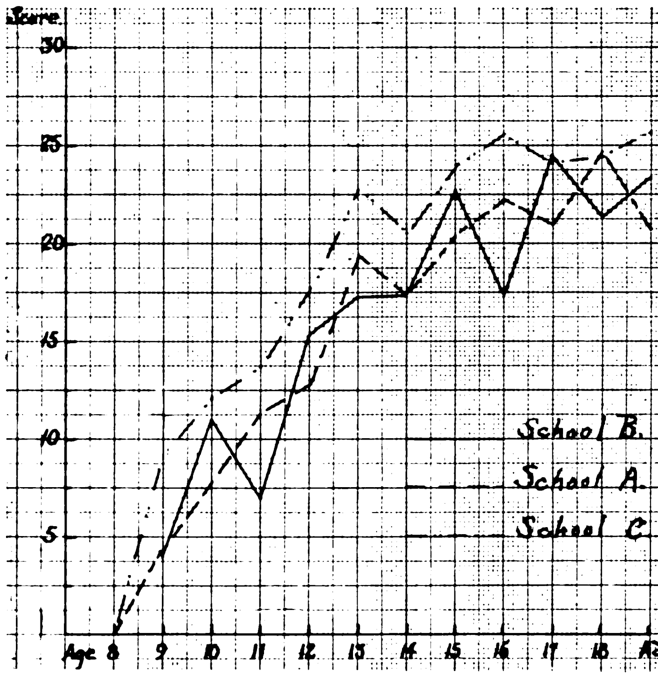
GRAPH 16. Digit-Symbol Test. Comparison of Congenital and Adventitious Cases in All Schools.



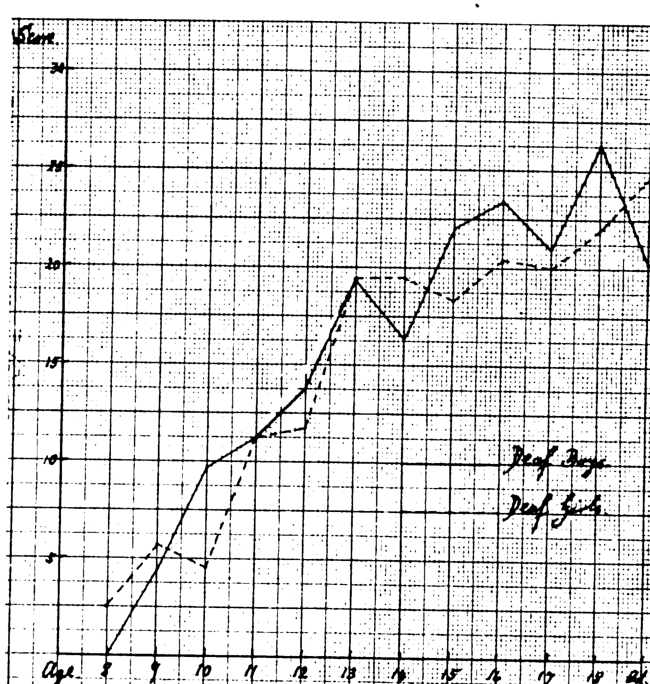
GRAPH. 17. Digit-Symbol Test. Distribution of Cases according to years retarded or accelerated.



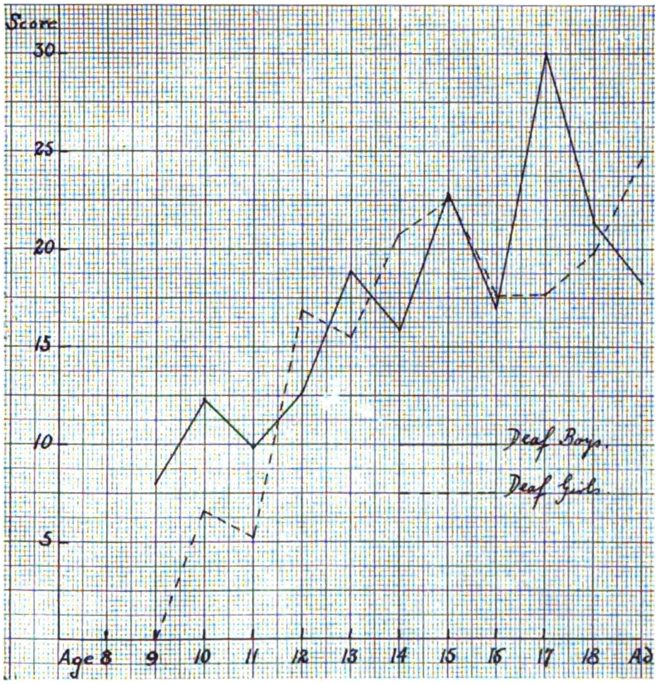
GRAPH 18. Symbol-Digit Test. Comparison of All Deaf in Three Schools.



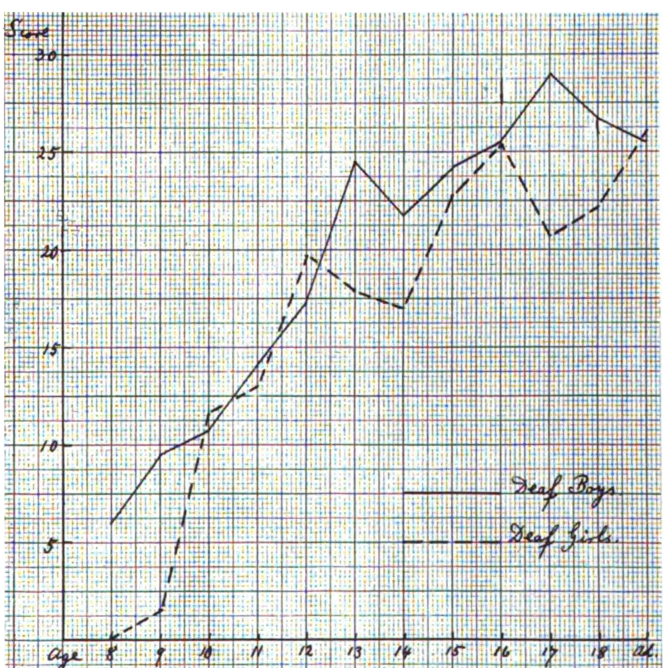
GRAPH 19. Symbol-Digit Test. Comparison of Boys and Girls. School A.



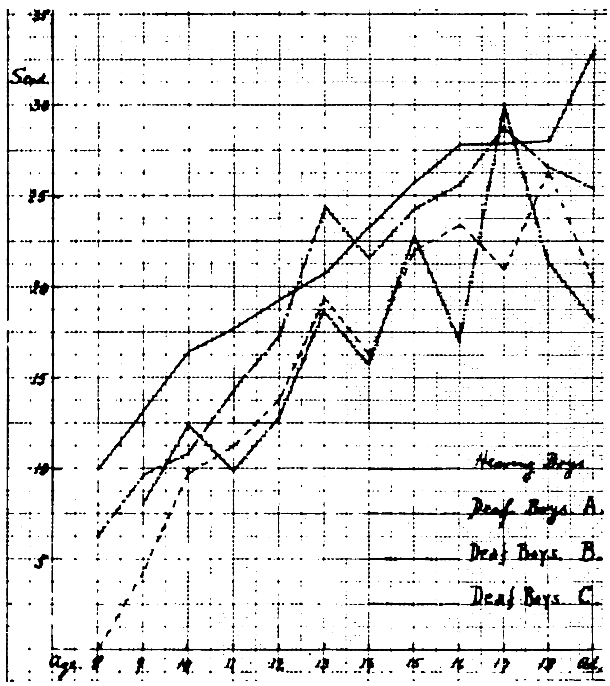
Graph 20. Symbol-Digit Test. Comparison of Boys and Girls. School B.



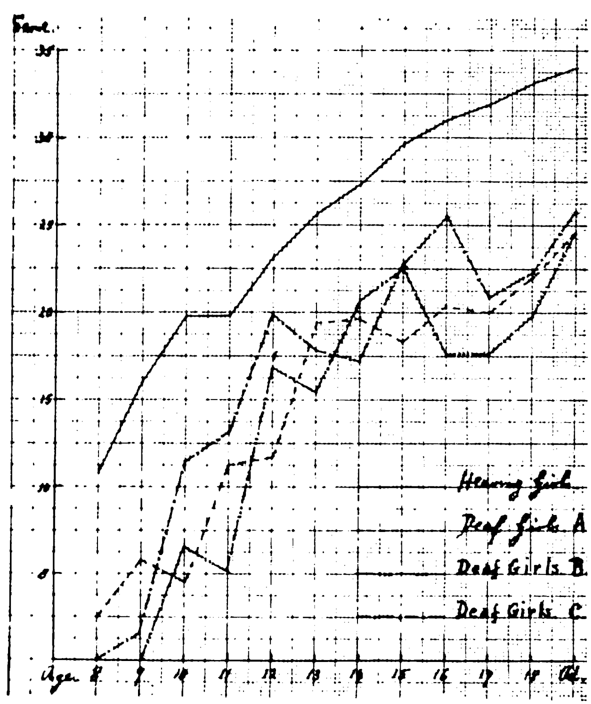
Graph 21. Symbol-Digit Test. Comparison of Boys and Girls. School C.



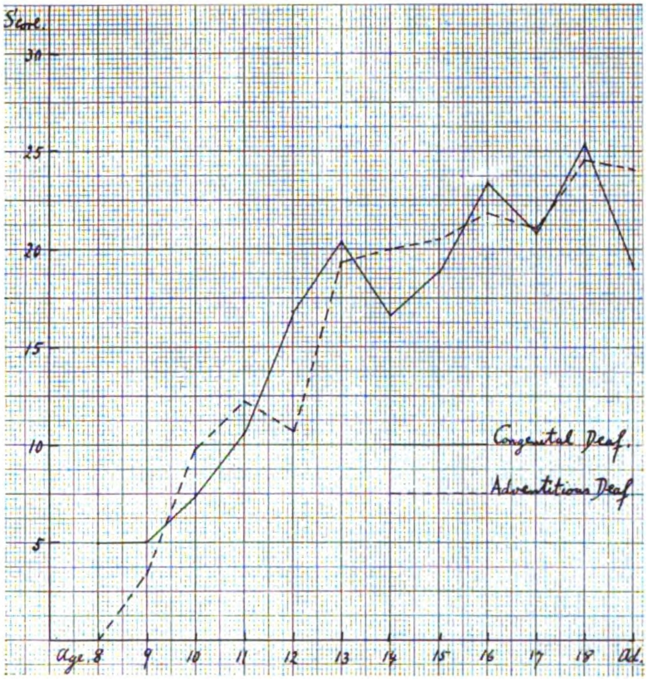
GRAPH. 22. Symbol-Digit Test. Comparison of Hearing Boys and Deaf Boys.



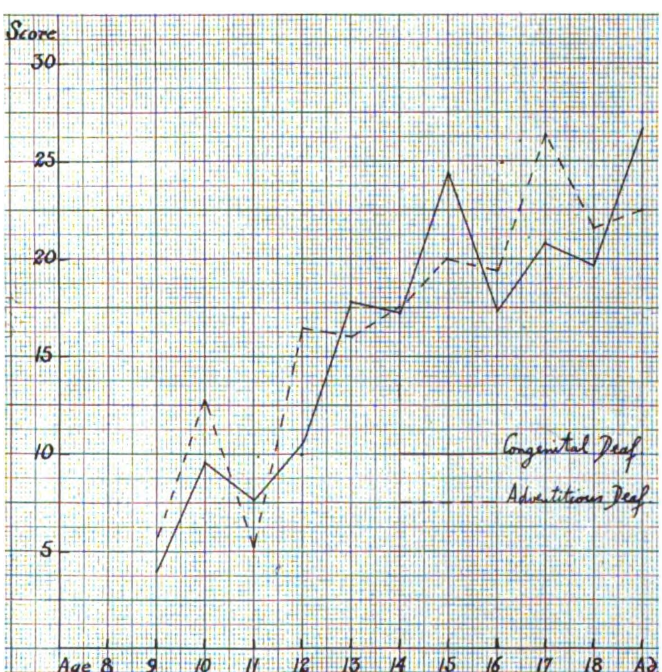
GRAPH 23. Symbol-Digit Test. Comparison of Hearing Girls and Deaf Girls.



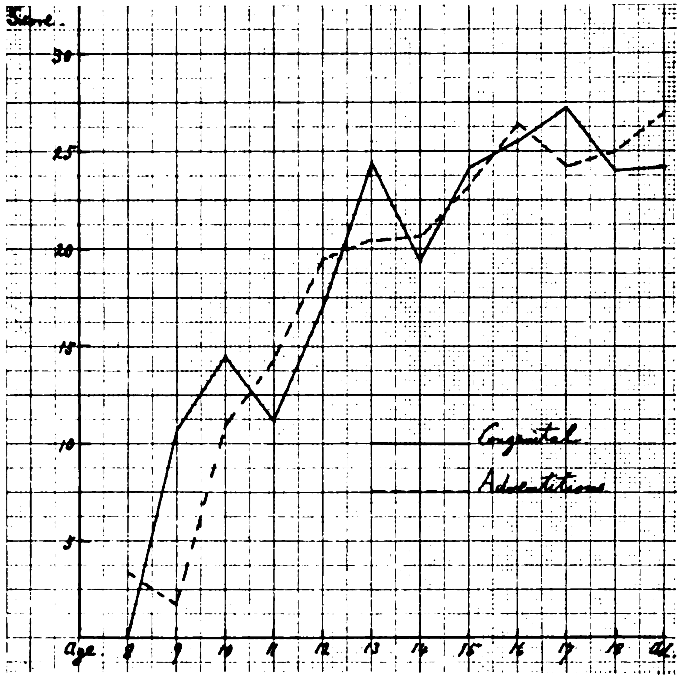
Graph 24. Symbol-Digit Test. Comparison of Congenital and Adventitious Cases. School A.



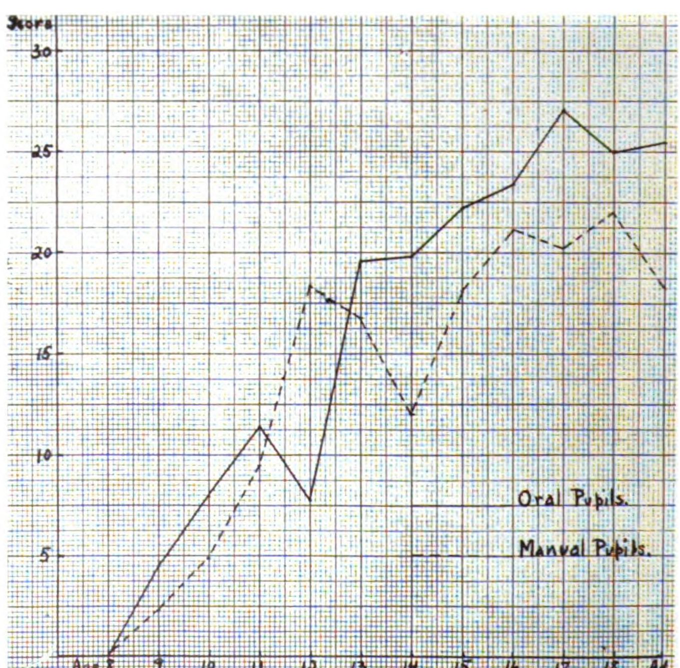
Graph 25. Symbol-Digit Test. Comparison of Congenital and Adventitious Cases. School B.



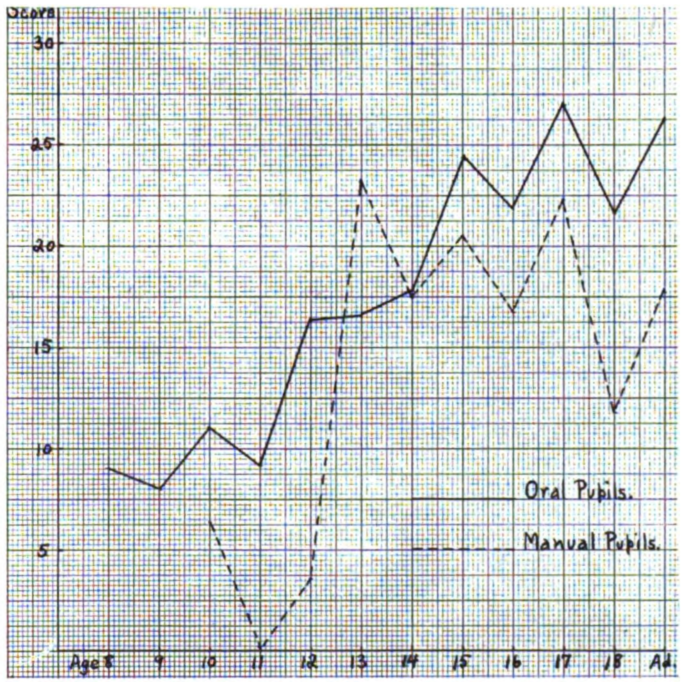
GRAPH 26. Symbol-Digit Test. Comparison of Congenital and Adventitious Cases. School C.



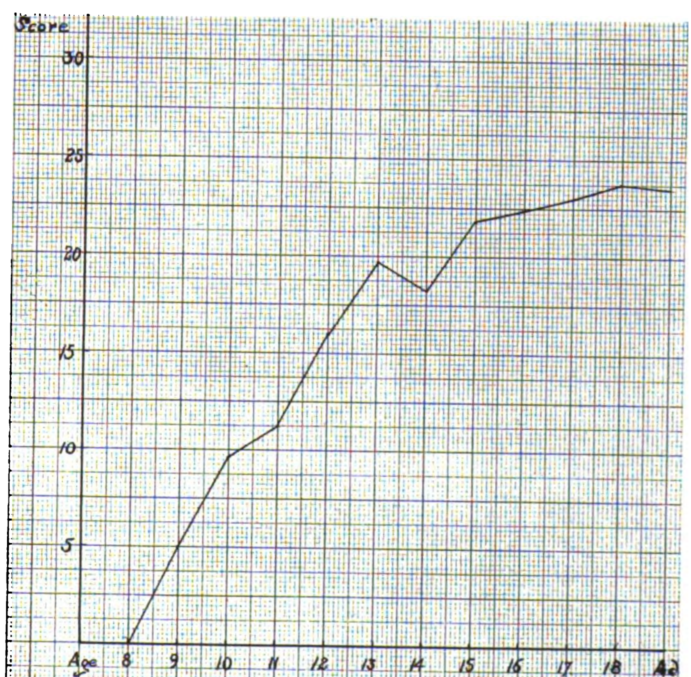
GRAPH. 27. Symbol-Digit Test. Comparison of Oral and Manual Pupils. School A.



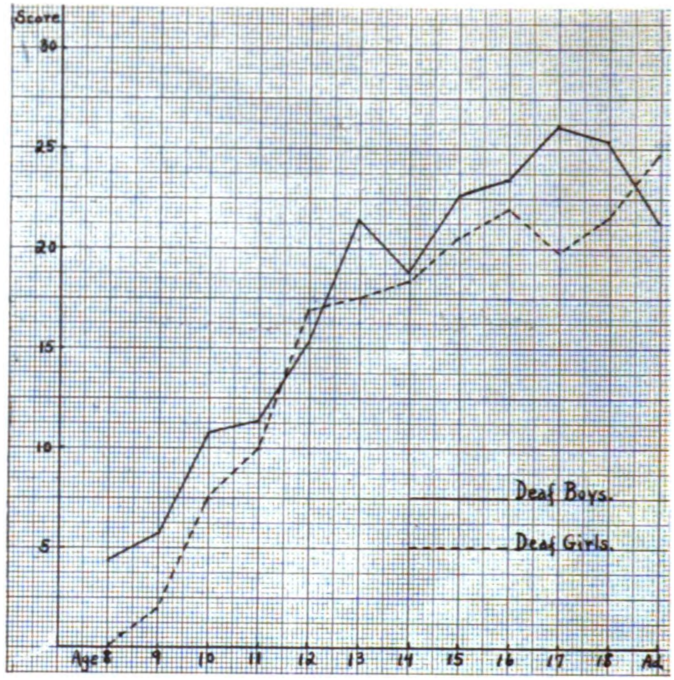
GRAPH 28. Symbol-Digit Test. Comparison of Oral and Manual Pupils. School B.



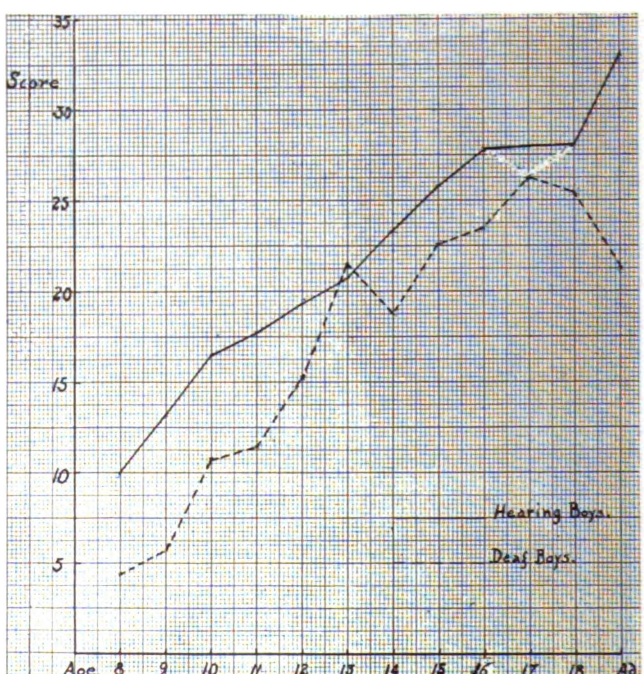
GRAPH. 29. Symbol-Digit Test. Age Norms for All the Deaf.



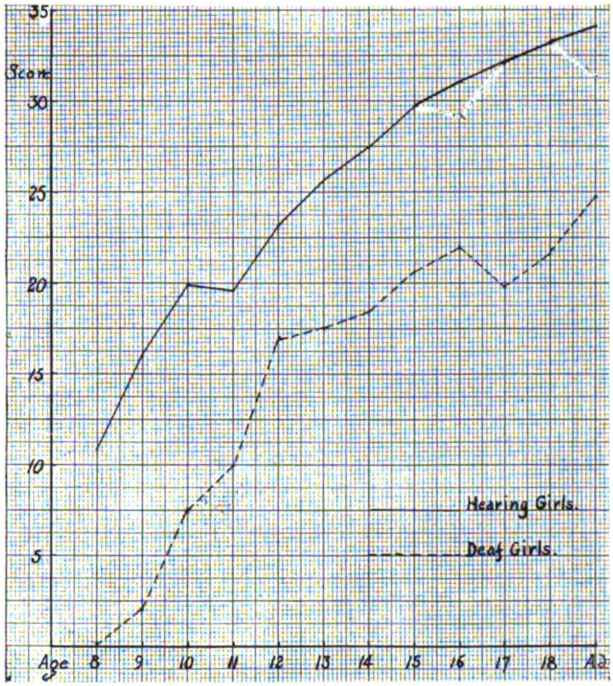
Graph. 30. Symbol-Digit Test. Comparison of Boys and Girls of All Schools.



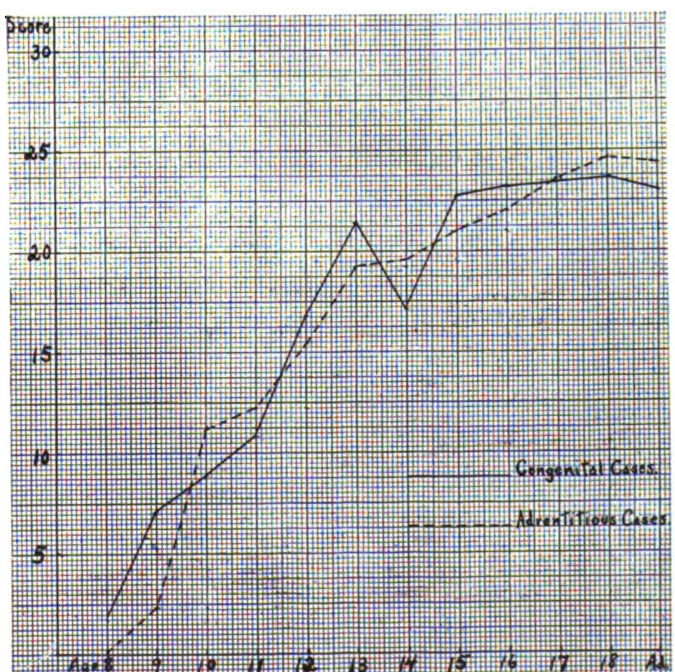
Graph 31. Symbol-Digit. Comparison of Hearing Boys and Deaf Boys of All Schools.



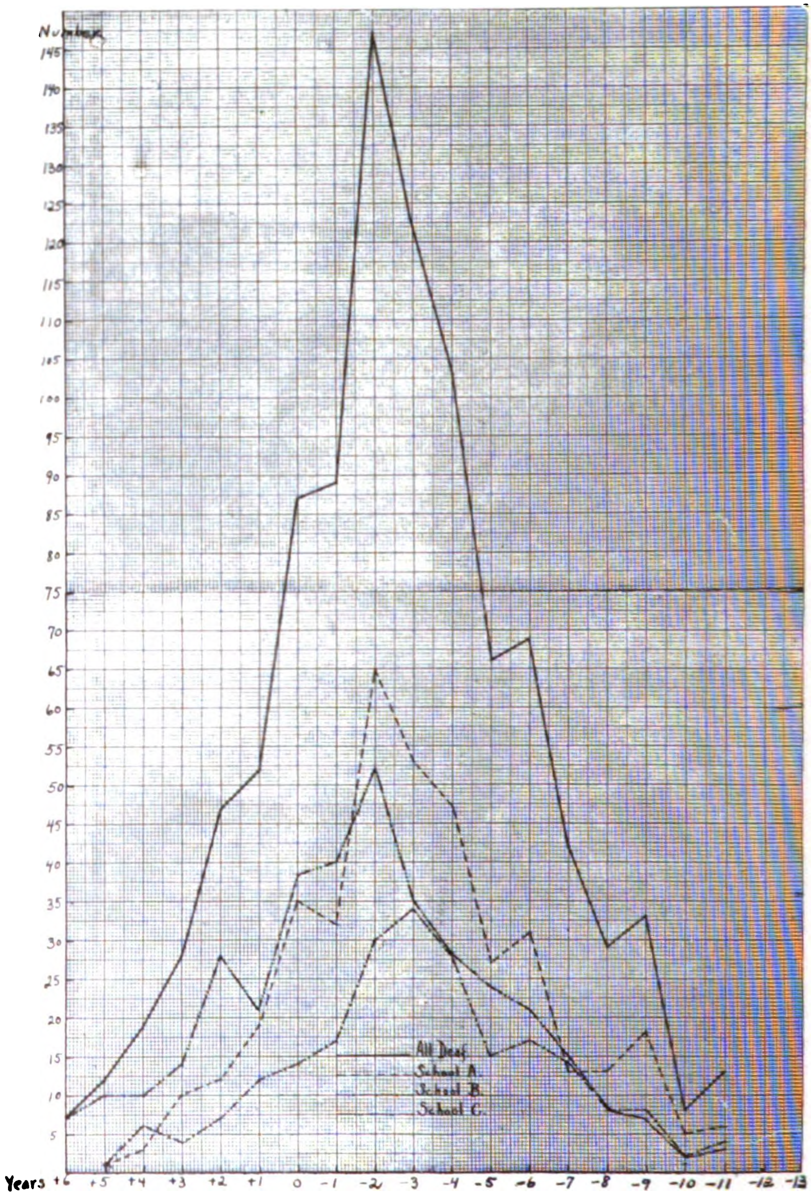
Graph 32. Symbol-Digit Test. Comparison of Hearing Girls and Deaf Girls of All Schools.



Graph 33. Symbol-Digit Test. Comparison of Congenital and Adventitious Cases in All Schools.



GRAPH 34. Symbol-Digit Test. Distribution of Cases according to years retarded or accelerated.



Graph 35. Average of Both Tests. Distribution of Cases according to years retarded or accelerated.